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## ORIGINAL ARTICLES.

### Pliocene (Tertiary) and Early Pleistocene (Quaternary) Mammalia of East Anglia, Great Britain, in Relation to the Appearance of Man.

By Henry Fairfield Osborn.

IN studying the evolution and distribution of the Proboscidea and the arrival of man in Great Britain (Osborn, 1922, 1922*a*, 1922*b*), the writer has recently had occasion to review the faunal researches of Lydekker and Newton, and the collection of Mr. A. C. Savin, in connexion with the very interesting question of the geologic correlation of Great Britain with the Upper Pliocene fauna of Europe to the south-east, and of the Scandinavian Glaciation I on the north, with the advent of the northern forest, the boreal, and the Arctic mammal fauna of Great Britain.

A résumé of the geologic conditions cited by Geikie (1882) and Prestwich (1871), more recently reviewed by Clement Reid (1890), is as follows :—

The south-eastern counties of England began to subside toward the close of the Pliocene and some fluviomarine sandbanks and shelly deposits were laid down, termed "Crag", and subdivided, according to their proportion of living species, into the following descending series :—

| | Feet. |
|---|---|
| Forest Bed group . . . . . | 10 to 70 |
| Exposed for many miles at the base of glacial deposits of cliffs on north-east coast of Norfolk. | |
| Chillesford beds—Chillesford Clay [= Weybourn Crag]. | 1 „ 8 |
| Chillesford Sand with shells . . | 5 „ 8 |
| A thin local deposit in Suffolk. Two-thirds of the Mollusca still live in Arctic waters. | |
| Norwich Crag . . . . . | 5 „ 10 |
| Fluviomarine or Mammaliferous Crag: of Mollusca, 93 per cent still living; northern species of molluscs, e.g. *Astarte borealis*, forerunners of Arctic invasion. | |
| Red Crag . . . . . | 25 |
| Of Mollusca, 92 per cent still living; of corals, 14 out of 25 species still native. | |
| White Crag . . . . . | 40 „ 60 |
| (Suffolk, Coralline, or Bryozoan Crag.) | |

According to Prestwich (*fide* Geikie, 1882, p. 872), the evidence of change of climate derivable from the English Pliocene Mollusca may be grouped as follows :—

| | Molluscan species now restricted to Northern Seas. | Southern Seas. |
|---|---|---|
| Norwich Crag . . | 19 | 11 |
| Red Crag . . . | 23 | 32 |
| White Crag . . | 14 | 65 |

According to Clement Reid (1890, p. 6), "The 'Nodule Bed' seems to be nearly co-extensive with the Red Crag, and probably also with the Coralline Crag, though often too thin to be of any economic importance. . . . A large proportion of the [mammalian] fossils appears to belong to a period somewhat earlier than the Crag, though still truly Pliocene, . . ."

According to the same author (op. cit., p. 139), "The most probable view seems to be that the two deposits [Chillesford, Weybourn] are synchronous, and that the Chillesford Clay passes laterally into the Weybourn Crag, or, at any rate, that the Weybourn Crag is equivalent to the upper part of the Chillesford Clay."

During the writer's visit to Cromer, accompanied by Mr. J. Reid Moir, he had the good fortune to examine the remarkable collection made by Mr. A. C. Savin. The writer is indebted to Mr. Savin for a letter, dated 21st November, 1921, together with notes, from which the following quotations are taken.

NOTES AND OBSERVATIONS BY MR. A. C. SAVIN: QUOTED WITH SLIGHT MODIFICATIONS AND OMISSIONS.

"I enclose a list of the *Forest Bed* vertebrates up to date, but there are still several forms to add later on. Mr. M. A. C. Hinton has a lot of my smaller things which he is now at work on. These include new voles, hare, hedgehog, etc. He hopes to publish the result shortly. One interesting addition is *Felis spelæa*, which is new to the Forest Bed.

"I have made a few notes relative to the horizon of the various species, from which you will gather that I do not think it possible to assign any particular level to any one species. I record in my catalogue the exact locality of each specimen, but cannot find a hard and fast horizon for any one species.

"*Proboscidea*.—At Mundesley some of the large bones of *Elephas meridionalis* in the 'Gunn Collection' were gotten out of the 'Pan' at a high level, i.e. 4 feet above the beach; on the other hand, others were obtained from a deep low or scour half-way down the beach, quite 15 feet lower down, and so on with most of the other animals. *Elephas meridionalis* is found generally all along the coast, but mainly at Mundesley and Bacton in the 'Pan' (gravel with oxide of iron) at the base of the cliff, also in the 'lows' or places scoured out half-way down the beach, in a greenish sandy clay. I do not think any definite horizon can be given; this applies also to *antiquus* and *primigenius*.

"No *Mastodon* remains have ever been found on the Norfolk coast; they only occur in the Red Crag of Suffolk and the Norwich

Crag near that city. There is no Crag on the coast (except the Weybourn Crag) and the *Mastodon* has been found on this coast only near Norwich, in the Norwich Crag, which is quite distinct from the Weybourn Crag. The mammals and shells in the Norwich Crag are of a different period altogether. The Red Crag does not occur upon the coast of Cromer. It is found chiefly in Suffolk, where it rests upon the London Clay. Between the Red and the Weybourn Crags the Norwich Crag occurs.

"The lowest division of the Forest Bed series, i.e. the *Lower Freshwater Bed*, is only known from cakes of peat thrown up on the beach after storms. I believe there was a fragment of it showing years ago at low-water between East Runton and Cromer, a tough greenish clay resting on the Chalk, with a few fish-bones in it. It is either washed away or out to sea and not uncovered by the tide, as I have not seen it for many years. The Forest Bed on the foreshore at East Runton is often so mixed up with the shelly Weybourn Crag that it is very difficult to say which bed the bones are in. The vole, shrew, myogale, and other small forms are rarely found. The Weybourn Crag rests on a layer of large flints which are embedded in the Chalk.

"The *Upper Freshwater Bed*, West Runton, contains nearly all the Forest Bed land mammals, but only fragments of elephants' teeth, and up to the present no hippopotamus.

"The divisions of the Forest Bed do not occur in the cliffs at Cromer. Clement Reid shows only the Contorted Drift above the Pliocene beds at Cromer.

"The Chalky Boulder-clay, which in point of time comes after the Boulder gravels, does not occur in the cliffs of the Norfolk coast.

"The Arctic Freshwater Bed (*Leda myalis*) is on the approximate level of ordinary high tide."

## Past and Present Faunal Lists of Crag and Forest Bed Vertebrates.

The accompanying faunal lists are those derived from the valuable papers of Lydekker (1886, 1887, 1891), Newton (1880, 1887, 1890), Reid (1890), Leney (1902), Hinton (1902–1914), a bibliography of the latter being given at the close of this paper. Most complete and most recent is the list prepared at the writer's request by Mr. A. C. Savin, largely based on his own collections and observations and carefully classified. To this list have been prefixed certain notes on synonymy according to American usage. This list is also amplified by a number of faunistic insertions kindly entered by Mr. Hinton, which are placed in square brackets [].

The writer is greatly indebted to the authorities of the British Museum, and especially to Mr. Martin A. C. Hinton, for the valuable notes, comments, and additions which he has inserted throughout the text, each of these notes being accompanied in the present printing by his initials (M. A. C. H.).

*Mammals, Extinct.*—Probably not one of the species occurring in the Forest Bed series, or in the older deposits mentioned in this paper, is identical with any form now existing. The references to recent species made by earlier writers on the subject were based either upon imperfect material or misconceptions. Each form as it becomes known by proper material proves to be extinct; but in the case of several of the species the material is still only sufficient to permit of a generic determination. This was the opinion of Dr. Forsyth Major, expressed about 1908 in the GEOLOGICAL MAGAZINE, and, after many years' work on Forest Bed remains, it has become my opinion also. (M. A. C. H.)

Reference should be made to Kennard, "The Pleistocene Succession in England," *Proc. Prehist. Soc. East Anglia*, vol. ii, part ii, 1916, and to the papers of Hinton and Forsyth Major cited therein.

*Derived Specimens.*—The faunal lists are complicated by the presence of *derived* specimens washed into these fluviatile formations from underlying beds, especially from such ancient beds as the Eocene London Clay, e.g. *Hyracotherium*, *Coryphodon*; also possibly from Pliocene beds, e.g. *Mastodon longirostris*, *Rhinoceros schleiermacheri*. These certainly derived specimens and species are also placed in square brackets [] to indicate that they are of older age or are species wrongly referred. There is, for example, no possibility that the Lower Pliocene species *Mastodon longirostris* Kaup occurs in the Red Crag.

These faunal lists are, therefore, of a preliminary character, but it is hoped that they will serve a useful purpose in the advance of our knowledge of Pliocene and Pleistocene correlation, on which the author has been engaged for many years.

MAMMAL FAUNA OF THE RED CRAG AND UNDERLYING NODULE-BED.

MAMMAL FAUNA OF THE NORWICH CRAG.

Newton, E. T., "On Some New Mammals from the Red and Norwich Crags": *Quart. Journ. Geol. Soc., London*, vol. xlvi, 1890, pp. 444–53.

*Lutra dubia.* Similar to Sansan species. (Nodule-bed.)

*Phoca Moori* Newt. Similar to Belgian form. (Nodule-bed.)

*Phocanella minor* Van Beneden. Similar to Belgian Pliocene specimens. (Nodule-bed.)

*Trogontherium minus* Newt. Similar to *T. Cuvieri*. (Nodule-bed.)

*Mesoplodon floris* Newt. Similar to *M. Floweri* of Red Crag of Suffolk.

*M. scaphoides* Newt. Similar to *Belemnoziphius* Huxley. (Nodule-bed.)

*Ailurus anglicus* Dawk. Similar to specimens Red Crag of Suffolk (racoon ?); also to *A. fulgens*. (Nodule-bed.)

*Lutra Reevei* Newt. Similar to *L. (Enhydriodon) sivalensis*.

[Referred to *Latax* by Pohle, *Archiv. f. Naturg.*, 1919 (1920), Abt. A, Heft 9, p. 167. M. A. C. H.]

Lydekker, R., "Note on Some Vertebrata from the Red Crag": *Quart. Journ. Geol. Soc., London*, vol. xlii, 1886, pp. 364–8; *Catalogue of the Fossil Mammalia in the British Museum*, Part IV, 1886, pp. 26, 55, 113.

Leney, Frank, "A List of the Type, Figured, and Described Fossils in the Norwich Castle Museum": GEOL. MAG., 1902, pp. 166–71, 220–31.

*Hyæna antiqua* Lank. = *H. striata* (*fide* Lyd.). Similar to *H. arvernensis*.

*Mastodon arvernensis*. Frequent (cf. Lyd. *Brit. Mus. Cat.*, 1886, pt. iv, p. 55).

[*M.* ? *longirostris* (*fide* Lyd.)] (Probably a "derived" specimen. H. F. O.)

*M. Borsoni*. Three specimens in Brit. Mus. (*fide* Lyd., *Brit. Mus. Cat.*, 1886, p. 26).

*Sus palæochœrus*. Similar to *S. erymanthius*, Pikermi. [Probably four species of "*Sus*", two derived and two possibly contemporaneous. M. A. C. H.]

*Tapirus* ? sp. *arvernensis*. Similar to *T. elegans*, Up. Plioc., S. France.

*Hipparion* ? sp. *gracile*. Similar to *H. crassum* Gerv., Plioc. of France. (Possibly a "derived" specimen. H. F. O.)

*Rhinoceros* ? *Schleiermacheri*. (Possibly a "derived" specimen or wrongly referred. H. F. O.)

*R. etruscus* ?

*R.* ? *incisivus*. (Certainly "derived" or wrongly identified. H. F .O.)

*Diomedea* ? sp. (albatross). Southern Ocean.

*Elephas meridionalis*. Two specimens in Brit. Mus. (*fide* Lyd., *Brit. Mus. Cat.*, 1886, p. 113). (Is this similar to the typical *E. meridionalis* of Nesti ? H. F. O.)

*Suffolk Crag Cetacea.*

Lydekker, R., "The Cetacea of the Suffolk Crag": *Quart. Journ. Geol. Soc.*, London, vol. xliii, Feb., 1887, pp. 7–18.

*Belemnoziphius* Huxley.

*Balæna primigenia*. Similar to Belgian form.

*Balænoptera*.

*Herpetocetus*.

*Eucetus*.

*Balænodon*.

*Hyperoodon*.

*Squalodon*.

*Orca*.

*Uria troile* (guillemot). Lyd., *Ibis*, vol. iii (6), 1891, p. 395.

*Mastodon arvernensis*. *Fide* Lyd. *Brit. Mus. Cat.*, 1886, pt. iv, pp. 54–5.

*Elephas meridionalis*. *Fide* Lyd. *Brit. Mus. Cat.*, pt. iv, 1886, p. 113; *Depéret, Mém. Soc. Geol. France Paléon.*, Mem. No. 3, 1890, pp. 190–1; two specimens in Norwich Castle Mus., Leney, GEOL. MAG., 1902, p. 171.

*Cervus* sp. Three specimens Gunn Coll., Norwich Castle Mus., Leney, GEOL. MAG., 1902, p. 168.

*C. Sedgwickii*. Norwich Castle Mus., Leney, GEOL. MAG., 1902, p. 167.

*Delphinus delphis*. Norwich Castle Mus., Leney, GEOL. MAG., 1902, p. 168.

*Arvicola* (*Evotomys*) *intermedius*. Norwich Castle Mus., Leney, GEOL. MAG., 1902, p. 166.

[*Arvicola* does not occur; all these remains are referable to *Mimomys* and most of them to *M. pliocænicus* Forsyth Major, *Proc. Zool. Soc.*, 1902, i, p. 102. M. A. C. H.]

Reid, Clement, "The Pliocene Deposits of Britain": *Mem. Geol. Surv. United Kingdom*, 1890, Appendix I, Table I (by E. T. Newton).

(Nodule-Bed.)

**Felis pardoides* Owen.
**Canis lupus* Linn.
*C. ? primigenius* Lank.
[*Pterodon* ? sp. (Eoc.).] (Derived. H.F.O.)
**Hyæna striata* Zimm.
*Hyænarctos.*
*Ailurus anglicus* Dawk.
*Ursus arvernensis* ? Cr. & Job.
*Lutra dubia* Blainv.
*Antilope* ?
*Machærodus* ?
**Lutra vulgaris* ?
*L. Reevei* Newt.
*Gazella anglica* Newt.
*Cervus ardeus* Cr. & Job.
*C. carnutorum* Lang.
*C. Falconeri* Dawk.
*C. suttonensis* Dawk.
*Equus Stenonis* Cocchi.
*Mastodon arvernensis* Cr. & Job.
*Elephas* [?] *antiquus* Falc.

* Important Note.—No *recent species really occur*; specimens referred to recent species are either misdetermined or else too fragmentary to permit of exact determination.—M. A. C. H.

Mammal, Bird, and Fish Fauna of the Norwich Crag.

*Cervus dicranoceros* Nesti.
*C. Falconeri* Dawk.
*C. suttonensis* Dawk.
*C. verticornis* Dawk.
*Xiphodon platyceps* Flower [Eoc.].
*Sus antiquus* ? Kaup.
*S. palæochœrus* Kaup.
**Equus caballus* Linn. ?
*Hipparion gracile* Kaup.
[*Rhinoceros* ? *incisivus* Kaup.] (Reference erroneous. H. F. O.)
[*R. Schleiermacheri* Kaup.] (Reference erroneous. H. F. O.)
*Tapirus arvernensis* Dev. & Bou.
[*Hyracotherium leporinum* Owen.] (Derived from London Clay. H. F. O.)
[*Coryphodon.*] (Derived from London Clay. H. F. O.)
*Mastodon arvernensis* Cr. & Job.
*M. Borsoni* Hays.
[*M.? longirostris* Kaup.] (Derived, or erroneous. H. F. O.)
*Elephas meridionalis* Nesti.
**Castor fiber* Linn.
*C. veterior* Lank.
*Trogontherium minus* Newt.
*Acipenser.*
*Elephas meridionalis* ?
*Arvicola intermedius* Newt.
*Trogontherium Cuvieri* Owen.
*T. minus* Newt.
*Uria troile* Linn.
*Mergulus.*
*Acipenser.*

Adams, A. Leith, *Monograph on the British Fossil Elephants*, 1877–81, London.

*Elephas antiquus.*
*Elephas antiquus.*

PARTIAL SUMMARY OF THE ABOVE LISTS.

| Types of Animals which make their Last Appearance in the Upper Pliocene Red Crag and the Norwich Crag and do not Survive into the Forest Bed. | Upper Pliocene Red and Norwich Crag Types which Survive in the Forest Bed. | Pleistocene Types which First Appear in the Forest Bed. |
|---|---|---|
| *Ailurus anglicus.* | *Elephas meridionalis.* | *Elephas primigenius.* |
| *Mastodon arvernensis.* | *E. antiquus.*[1] | *Equus caballus fossilis.* |
| *M. Borsoni.* | *Hyæna striata.* | *Rhinoceros megarhinus.* |
| *Hipparion ? gracile.* | *H. antiqua.* | *Hippopotamus amphibius* |
| *Rhinoceros ? Schleiermacheri.* | *Rhinoceros etruscus.* | *Sus scrofa.* |
| *Rhinoceros ?* | *Equus stenonis.* | *Bison bonasus.* |
| *Halitherium ?* sp. | *Cervus carnutorum.* | *Caprovis Savinii.* |
| *Felis ? pardoides.* | *Machærodus ?* sp. | *Ovibos moschatus.* |
| *Hyænarctos ?* sp. | *Trogontherium Cuvieri.* | *Alces latifrons.* |
| *Ursus ? arvernensis.* | | *Capreolus capreolus.* |
| *Antilope ?* sp. | | *Cervus elaphus.* |
| *Gazella anglica.* | | *Ursus spelæus.* |
| *Trogontherium minus.* | | *Felis spelæa* |
| *Sus palæochærus.* | | *Macacus.* |
| *Tapirus arvernensis.* | | Varied forest rodent fauna. |
| | | Northern forest small carnivora. |

Mammal fauna of East Anglia in Upper Pliocene time closely similar both in generic and specific types to the mammal fauna of northern Italy, Val d'Arno, also of the Upper Pliocene of southern France.

CONCLUSIONS.

The Norwich Crag presents a distinct advance over the Red Crag in its mammalian, as well as in its molluscan fauna; it is more modern. The correlation of the Red Crag and, in a less degree, of the Norwich Crag with the *Val d'Arno supérieur* of northern Italy, is very close indeed, as long ago observed by Hugh Falconer, and marks the close of Pliocene time in Great Britain.

(1) The two Crags contain the prevailing forest-loving fauna of a warm north temperate climate with certain African, south Eurasiatic, and a very few north Eurasiatic elements such as *Trogontherium*.

(2) The post-Crag extinction of at least fourteen types of mammals, notably *Mastodon arvernensis*, *M. Borsoni*, *Gazella*, *Tapirus*, marks the advent of a cold period in Great Britain as it does in northern Italy.

(3) The Forest Bed arrival of tundra and northern forest types, such as *Elephas primigenius*, *Ovibos moschatus*, *Alces latifrons*, is a feature of the northern latitude of East Anglia during the period of

[1] *Fide* A. Leith Adams, *British Fossil Elephants*, 1877–81, pp. 13, 14, pl. xxvi; Richard Lydekker, *Catalogue of Fossil Mammalia*, 1886, pt. iv, pp. 123, 124; Guy E. Pilgrim, "On the Occurrence of *Elephas Antiquus* (*Namadicus*) in the Godavari Alluvium, with Remarks on the Species, its Distribution, and the Age of the Associated Indian Deposits": *Rec. Geol. Surv., India*, xxxii, pt. iii, 1905, p. 217.

the first Scandinavian glaciation, which has no parallel in southern France or in northern Italy.

(4) The survival from the Red and Norwich Crags in the Forest Bed of warm temperate types, such as *Elephas meridionalis*, *E. antiquus*, *Hyæna striata*, *Rhinoceros etruscus*, *Equus stenonis*, *Machærodus*, is exactly paralleled by the same genera and species occurring in southern France and northern Italy during the long, warm First Interglacial period. During this period there appear for the first time in Great Britain certain African types, like the *Hippopotamus*, and there become more abundant in Great Britain the African elephant type, *Elephas* (*Loxodonta*) *antiquus*, as well as the *Hyæna*.

(5) Both in northern Italy and in East Anglia the forests become filled with a highly varied cervine fauna, including a great variety of species of deer. There is also a rich rodent fauna, and forest types of carnivores like the bear.

The Red and Norwich Crags and the successive faunal divisions of the Weybourn and Forest Bed wholly justify the conclusion of James Geikie that we have abundant proofs in East Anglia of the close of Pliocene and of the beginning of Pleistocene conditions. Man appears in Britain under true Tertiary conditions of the climate, of the fauna, of the flora. Two points are clearly established :—

First : The discovery of remains of human (Foxhallian) industry within and beneath the Red Crag *adds the highest Primate to this fauna*, namely, a species of man probably referable either to *Homo* or to *Eoanthropus*, as made known through the researches of J. Reid Moir and E. Ray Lankester. Second : The next appearance of man is in the Cromerian industry of the base of the Forest Bed, immediately overlying the Weybourn, also made known through the researches of Moir and of Lankester. This is no longer Tertiary man, but Quaternary man, found with a true Lower Quaternary fauna and flora closely comparable to that of southern France and of the 40th parallel in the United States.

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1902. "Note on the Occurrence of *Microtus intermedius* in the Pleistocene Deposits of the Thames Valley" (with Gilbert White) : Proc. Geol. Assoc., xvii, pp. 414, 415.

# LIST OF VERTEBRATA FOUND IN THE "FOREST BED" SERIES OF NORFOLK AND SUFFOLK.

| Notes or Synonymies given by American Museum Zoologists. Also by Mr. Martin A. C. Hinton. | List by Mr. A. C. Savin. | Survivors from Nodule-Bed, Red Crag, and Norwich Crag.—H. F. O. | Weybourn Crag. | Lower Freshwater Bed. | Middle Freshwater Bed. | Upper Freshwater Bed. | Rarity.—Frequency. | Notes by Mr. A. C. Savin |
|---|---|---|---|---|---|---|---|---|
| **PISCES.** | | | | | | | | |
| *Perca fluviatilis.* | *Perca fluviatilis.* | | | | × | × | C. | Fairly common at W. Runton, Up. Freshwater Bed. |
| *Acerina acerina.* | *Acerina vulgaris.* | | | | | × | 1 | One otolith at W. Runton, Up. Freshwater Bed. |
| *Esox lucius.* | *Esox lucius.* | | | | | × | V.C. | Very common at W. Runton, Up. Freshwater Bed. |
| *Barbus barbus.* | *Barbus vulgaris.* | | | | | × | 2 | Found at W. Runton, Up. Freshwater Bed. |
| *Leuciscus cephalus.* | *Leuciscus cephalus.* | | | | | × | 1 | Jaw with two teeth from Ostend, Up. Freshwater Bed (near Bacton). |
| *Rutilus rutilus.* | *Leuciscus rutilus.* | | | | | × | V.C. | Very common at W. Runton, Up. Freshwater Bed. |
| *Scardinius erythrophthalmus.* | *Leuciscus erythrophthalmus.* | | | | | × | V.R. | Very rare at W. Runton, Up. Freshwater Bed. |
| *Abramis brama.* | *Abramis brama.* | | | | | × | 2 | Two teeth at W. Runton, Up. Freshwater Bed. |
| *Tinca tinca.* | *Tinca vulgaris.* | | | | | × | C. | Common at W. Runton, Up. Freshwater Bed. |
| *Platax woodwardi.* | *Platax woodwardi.* | | × | | × | | C. | Common in both deposits. |
| *Gadus morrhua.* | *Gadus morrhua.* | | × | | × | | R. | Rare, E. Runton, Overstrand, Trimingham, in both deposits. |
| *Pollachius pollachius.* | *Gadus pollachius.* | | × | | | | 2 | Two otoliths, E. Runton. |
| *Thunnus thynnus.* | *Thynnus thynnus.* | | × | | | | 1 | Vertebra, E. Runton. |
| *Pleuronectes* sp. | *Platessa* sp. | | | | × | | 1 | Left maxilla, Overstrand. |
| *Acipenser* sp. | *Acipenser* sp. | × | | | × | | V.R. | A few dermal plates, E. Runton Sidestrand, Mundesley. |
| *Mustelus canis.* | *Galeus canis.* | | × | | | | 3 | Teeth, E. Runton. |
| *Squalus acanthias.* | *Acanthias vulgaris.* | | × | | | | 2 | Teeth, E. Runton. |
| *Raja batis.* | *Raja batis.* | | × | | | | R. | Teeth. |
| *Raja clavata.* | *Raja clavata.* | | × | | | | R. | Teeth and dermal defenses, E. Runton. |
| *Gadus pseudæglefinus.* | *Gadus pseudæglefinus.* | | × | | | | 1 | One otolith, E. Runton. |
| **AVES.** | | | | | | | | |
| Goose. | *Anser* sp. | | | | × | | 1 | One metacarpal, E. Runton. |
| Mallard. | *Anas boschas.* | | | | | × | R. | Several bones, W. Runton, Up. Freshwater Bed. |
| Shoveller Duck. | *Spatula clypeata.* | | | | | × | 1 | Coracoid, W. Runton, Up. Freshwater Bed |
| Eagle Owl. | *Bubo maximus.* | | | | × | | 1 | Tarso-metatarsus, E. Runton. |
| Common Cormorant. | *Phalacrocorax carbo.* | | | | × | | 1 | Coracoid, W. Runton, Up. Freshwater Bed. |
| Bank Swallow—*Riparia riparia.* | *Hirundo riparia.* | | | | | × | 1 | Wing bone, W. Runton, Up. Freshwater Bed. |
| European Teal. | *Querquedula crecca.* | | | | | × | 1 | Left humerus, W. Runton, Up. Freshwater Bed. |
| European Wigeon. | *Marecca penelope.* | | | | | × | 1 | Wing bone, W. Runton, Up. Freshwater Bed. |
| *Diomedea* (albatross). | | | | | | | | |
| *Uria troile* (guillemot). | | | | | | | | |
| **REPTILIA.** | | | | | | | | |
| Ringed Snake—*Natrix natrix.* | *Tropidonotus natrix.* | | | | | × | V.R. | Vertebræ, W. Runton, Up. Freshwater Bed. |
| Adder—*Vipera berus.* | *Pelias berus.* | | | | | × | 2 | Vertebræ, W. Runton, Up. Freshwater Bed. |
| Slow Worm. | *Anguis fragilis.* | | | | | × | 2 | Vertebræ, W. Runton, Up. Freshwater Bed. |
| **AMPHIBIA.** | | | | | | | | |
| Common Frog. | *Rana temporaria.* | | | | | × | R. | Various bones, W. Runton, Up. Freshwater Bed. |
| Edible Frog. | *Rana esculenta.* | | | | | × | V.R. | Various bones, W. Runton, Up. Freshwater Bed. |
| Bufo sp. | *Bufo* sp. | | | | | × | V.R. | Various bones, W. Runton, Up. Freshwater Bed. |
| Great Warted Newt—*Triturus cristatus.* | *Triton cristatus.* | | | | | × | 1 | Femur, W. Runton, Up. Freshwater Bed. |
| **INSECTIVORA.** | | | | | | | | |
| European Mole. | *Talpa Europæa.* | | | | | × | C. | W. Runton and Bacton Up. Freshwater Bed. |
| *Sorex Savini.* | *Sorex Savini.* | | | | | × | C. | W. Runton. |
| *Sorex Runtonensis.* | *Sorex Runtonensis.* | | | | | × | C. | W. Runton. |
| Newton's Water Shrew. | *Neomys Newtoni.* | | | | | × | C. | W. Runton. |
| English Myogale = Galemys. | | | | | | | | |
| Continental Myogale = Desman. | *Myogale moschata.* | | | | | × | R. | W. Runton, one jaw at Bacton, Up. Freshwater Bed. |
| *Erinaceus* new sp. | *Erinaceus* new sp. | | | | | × | 1 | One tooth, W. Runton. |
| **CETACEA.** | | | | | | | | |
| *Balænoptera* sp. | *Balænoptera* sp. | × | | | × | | V.R. | A few large vertebræ, Overstrand, Mundesley, Bacton, Forest Bed. |
| *Monodon monoceros.* | *Monodon monoceros.* | | | | × | | 4 | Part of snout with aborted tusk and three pieces tusk, Overstrand. |
| *Delphinus delphis.* | *Delphinus delphis.* | × | | | × | | 2 | Vertebræ, Overstrand and Sidestrand, Forest Bed |
| *Delphinus* sp. | *Delphinus* sp. | | | | × | | 2 | Vertebræ, Overstrand and Sidestrand, Forest Bed. |
| *Balæna biscayensis.* | *Balæna biscayensis.* | | | | × | | 2 | Tooth, Sidestrand, Forest Bed. |
| *Physeter macrocephalus.* | *Physeter macrocephalus.* | | × | | × | | 1 | Cervical vertebra and tympanic bone, E. Runton. |
| *Orca gladiator.* | *Orca gladiator.* | × | | | × | | 2 | Dorsal vertebræ, E. Runton, and tooth, Pakefield, Forest Bed. |
| *Pseudorca crassidens.* | *Pseudorca crassidens.* | | | | × | | 1 | Atlas vertebra, Mundesley. |
| *Delphinapterus leucas.* | *Delphinapterus leucas.* | | × | | | | 1 | Caudal vertebra, E. Runton. |
| *Phocæna communis.* | *Phocæna communis.* | | × | | × | | 1 | Caudal vertebra, Sidestrand. |
| *Tursiops tursio.* | *Tursiops tursio.* | | | | × | | 1 | Vertebra. |
| Several vertebræ not identified. | | | | | | | | |
| **RODENTIA.** | | | | | | | | |
| *Trogontherium Cuvieri.* | *Trogontherium Cuvieri.* | × | | | × | × | V.R. | All along the coast in Up. Freshwater Bed and Forest Bed. |
| European Beaver. | *Castor Europæus* [*Castor exterior* Lankester.—M. A. C. H.] | × | | | × | × | V.R. | W. Runton, Overstrand, and Pakefield, Forest Bed and Up. Freshwater Bed. |
| *Castor plicidens.* | *Castor plicidens.* | | | | × | × | V.R. | W. Runton, Up. Freshwater Bed, and E. Runton, Forest Bed. |
| *Crictetus vulgaris runtonensis.*[1] | *Cricetus vulgaris runtonensis.* | | | | | × | 1 | W. Runton, Up. Freshwater Bed, one upper jaw. |
| Common Squirrel; Eng. subsp. *leucourus.*[2] | *Sciurus vulgaris.* | | | | | × | 1 | Humerus, Ostepd, Up. Freshwater Bed, and gnawed fir-cones in Forest Bed. |
| *Sciurus Whitei.* | *Sciurus Whitei.* | | | | | | | |
| Wood Mouse—*Apodemus sylvaticus.* | *Mus sylvaticus.* | | | | | × | 1 | One tooth, W. Runton, Up. Freshwater Bed. |
| | | | | | | × | V.R. | Jaws, teeth, and a few bones, Up. Freshwater Bed, and gnawed fir-cones in Forest Bed. |
| Hare. | *Lepus* sp. Hare. | | | | | × | 4 | Two teeth and two bones, Up. Freshwater Bed, and gnawed fir-cones in Forest Bed. |
| *Mimomys intermedius.* | *Mimomys intermedius.* | | | | | | | |
| *Mimomys Newtoni.*[3] | *Mimomys Newtoni.* | | | | × | × | C. | W. Runton, E. Runton, and Bacton. |
| *Mimomys Reidi.* | *Mimomys Reidi.* | × | | × | | | R. | At E. Runton. |
| *Mimomys Savini.* | *Mimomys Savini.* | | × | | | | R. | At E. Runton. |
| *Mimomys majori.* | *Mimomys majori.* | | | | | × | | W. Runton, Up. Freshwater Bed. |
| *Mimomys pliocænicus.* | *Mimomys pliocænicus.* | | | | | × | | W. Runton, Up. Freshwater Bed. |
| There are also about four species of *Microtus* at West Runton and two species of *Pitymys* all extinct. | | | × | | | | R. | E. Runton, Weybourn Crag. |
| *Ecotomys* sp. | *Ecotomys* sp. | | | | | × | | |
| [*Castor fiber* = *Castor* ? sp.][4] | | × | | | | | | |
| **PROBOSCIDEA.** | | | | | | | | |
| Straight-tusked Elephant. | *Elephas antiquus.* | × | | | × | × | C. | One tooth, W. Runton, Up. Freshwater Bed and Forest Bed, all along the coast. |
| Southern Mammoth. | *Elephas meridionalis.* | × | | | × | | C. | Mundesley and Bacton principally, but along the coast. |
| Hairy Mammoth. | *Elephas primigenius.* | | | | × | | V.R. | Overstrand, Sidestrand, Mundesley, and Bacton, Forest Bed. |
| **UNGULATA** (*Perissodactyla, Artiodactyla*). | | | | | | | | |
| | *Equus fossilis.* | | | | | | | |
| Steno's Horse. | *Equus stenonis.* | × | | | × | × | C. | Common all along the coast. |
| Etruscan Rhinoceros. | *Rhinoceros etruscus.* | × | | | × | × | V.R. | Common all along the coast. |
| *Rhinoceros megarhinus.* | *Rhinoceros megarhinus.* | | | | × | × | C. | Common all along the coast. |
| Hippopotamus. | *Hippopotamus amphibius.* | | | | × | | 1 | Premolar, Cromer. |
| Wild Boar, *Sus antiquus.* | *Sus scrofa*[5] ? *palæochærus.* | | | | × | | F.C. | All along the coast. |
| European Bison. | *Bison bonasus.* | | | | × | × | V.R. | Four teeth Sidestrand, Forest Bed. A few teeth and bones E. Runton. |
| *Caprovis Savinii.* | *Caprovis Savinii.* | | | | × | × | F.C. | All along the coast. |
| Musk-ox. | *Ovibos moschatus.* | | | | × | | 1 | Horn core, Overstrand. |
| *Alces latifrons.* | *Alces latifrons.* | | | | × | | 1 | Part of skull and horn cores at Trimingham, Forest Bed. |
| Roe Deer—*Capreolus capreolus* ? | *Capreolus caprea.* | | | | × | | R. | All along the coast. |
| *Cervus carnutorum* ? | *Cervus carnutorum* ? | × | | | × | | 2 | Two horns, Overstrand, Forest Bed. |
| *Cervus Dawkinsi.* | *Cervus Dawkinsi.* | | | | × | | | A dredged specimen which may be Forest Bed. |
| Red Deer. | *Cervus elaphus.* | | | | × | | V.R. | E. Runton, Overstrand, Mundesley, Forest Bed. |
| *Cervus elueriacum.* | *Cervus elueriacum.* | | | | × | | R. | E. Runton, Overstrand, Mundesley, Forest Bed. |
| *Cervus Polignacus.* | *Cervus Polignacus.* | | | | × | | V.R. | Only E. Runton, Forest Bed. |
| *Cervus Sedgwickii.* | *Cervus Sedgwickii.* | | | | × | | R. | E. Runton, Overstrand, Trimingham, Mundesley. |
| *Cervus verticornis.* | *Cervus verticornis.* | × | | | × | | R. | E. Runton, Overstrand, Trimingham, Mundesley. |
| *Cervus Fitchii.* | *Cervus Fitchii.* | × | | | × | × | C. | All along the coast. Skull and antlers, W. Runton, Up. Freshwater Bed. |
| *Cervus tetraceros.* | *Cervus tetraceros.* | | | | × | | V.R. | Mundesley. |
| *Cervus rectus.* | *Cervus rectus.* | | | | × | | V.R. | E. Runton, Forest Bed. |
| *Cervus Savini.* | *Cervus Savini.* | | | | × | | 1 | Sidestrand, Forest Bed. |
| | *Gazella anglica.* | × | | | × | | C. | All along the coast. |
| | *Gazella daviesii.* | × | | | | | | |
| **CARNIVORA.** | | | | | | | | |
| Cave Bear. | *Ursus savini.*[6] | | | | × | × | R. | Found all along the coast. |
| Fossil Grizzly Bear. | *Ursus ferox fossilis.* | | | | × | × | 2 | W. Runton and Mundesley. |
| Wolverine. | *Gulo luscus.* | | | | × | | 1 | Jaw, Mundesley. |
| Wolf ? sp. | *Canis lupus.* | × | | | × | × | V.R. | W. Runton, Up. Freshwater Bed, and a few places along the coast. |
| Red Fox—*Vulpes vulpes crucigera.* | *Canis vulpes.* | | | | × | × | V.R. | W. Runton, Up. Freshwater Bed, and a few places along the coast. |
| *Canis* sp. | *Canis* sp. | × | | | | | 4 | Jaw, tibia, pelvis, a premolar. E. T. Newton says dog or wolf, but some day will prove to be another species. |
| *Hyæna striata antiqua.* | *Hyæna* ? *striata.* | | | | | | | |
| Sabre-tooth Tiger. | *Machærodus* sp. | × | | | × | × | V.R. | W. Runton, E. Runton, Overstrand, Mundesley and Certon, Suffolk. |
| Pine Marten—*Martes martes martes.* | *Mustela martes.* | × | | | × | × | V.R. | W. Runton, E. Runton, Overstrand, and a jaw at Pakefield, Lowestoft. |
| Weasel—*Mustela nivalis nivalis.* | *Mustela vulgaris.* | | | | | × | 1 | W. Runton, Up. Freshwater Bed. |
| Otter—*Lutra lutra.* | *Lutra vulgaris.* | | | | | × | V.R. | W. Runton, Up. Freshwater Bed. |
| | | × | | | × | × | 3 | Jaw at E. Runton, and two bones from W. Runton, Up. Freshwater Bed. E. Runton, Forest Bed. |
| Fossil Walrus—*Odobænus.* | *Trichechus Huxleyi.* | | | | × | | 2 | Tusk, Overstrand, and humerus, Mundesley. |
| Bearded Seal—*Erignathus barbatus.* | *Phoca barbata.* | | | | × | | 2 | Humerus and radius, Overstrand. |
| *Phoca* sp. | *Phoca* sp. | × | | | × | × | 3 | W. Runton, tooth. Two bones, E. Runton. |
| Cave Lion. | *Felis spelæa.* | | | | × | | 1 | Lower Jaw from Pakefield, Suffolk, Forest Bed. Just received a letter from Dr. Smith Woodward stating that above specimen in my old collection is *F. spelæa*, new to the Forest Bed. |
| *Felis pardoides.* | | | | | | | | |
| **QUADRUMANA.** | | | | | | | | |
| *Macacus* sp.[7] | *Macacus* sp. | | | | | × | 1 | Distal end of humerus, W. Runton, Up. Freshwater Bed. |

[1] Should be given full specific rank.—M. A. C. H.
[2] No determinable trace of this species.—M. A. C. H.
[3] *Newtoni* does not occur in the Upper F. B., but in the Lower F. B. at East Runton, and perhaps in Norwich Crag.—M. A. C. H.
[4] For *Castor*, *Trogontherium*, and *Sciurus*, see Hinton (1914, p. 186) and works therein cited.
[5] Not *scrofa*, described as a new species in a paper now in press. *Proc. Geol. Assoc.*, Hinton, 1922.—M. A. C. H.
[6] *Ursus savini* Andrews (*Ann. Mag. Nat. Hist.*, Ser. IX, vol. ix, p. 204, February, 1922).—M. A. C. H.
[7] See Hinton (1908, p. 440).

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## Notes on the Doleritic Intrusions of East Fife.

By D. Balsillie, F.G.S.

THE following brief notes compiled mainly some years ago will, it is hoped, convey information supplementary to that provided in the Memoir on the Geology of Eastern Fife (Appendix, pt. ii), and are to be regarded as useful only where they furnish particulars not already available from that source.

The majority of the subsequently introduced igneous masses in East Fife belong to one or other of the two great series of doleritic intrusions that are now known to have such a wide distribution in Central Scotland, viz. (*a*) Quartz-dolerites and (*b*) Olivine-dolerites, including teschenites. The characters of these as developed in this area may be set forth as follows :—

(*a*) *Quartz-dolerites.*—Rocks of this type occur abundantly in East Fife, and an admirable description of one, though by no means the freshest member of the series, has been given by Dr. Flett (vide loc. supra cit.). But the petrographic details of the quartz-dolerites have now in other areas [1] been so thoroughly ascertained that it would be merely a repetition of familiar fact to elaborate these at length here. In the field there is a singular lack of uniformity in the character of these masses. Some are dark, fine-textured, and thoroughly basic looking, whereas others are coarse-grained and carry an abundance of pink felspar. Segregation veins and patches are characteristic of the quartz-dolerites, and another feature, one indeed almost of diagnostic value, so far at all events as the intrusive igneous rocks of East Fife are concerned, is the remarkably constant presence of a considerable content of iron sulphide either in the form of pyrite or marcasite.

Microscopically, the quartz-dolerites consist essentially of lime-soda felspar ranging up to a fairly basic labradorite or bytownite, orthoclase, generally in comparatively small amount, monoclinic pyroxene, sometimes two monoclinic pyroxenes—clino-enstatite and augite, and hypersthene. These minerals are enclosed in a highly felspathic or quartzo-felspathic groundmass that often shows micropegmatite. The latter varies greatly in amount, sometimes being present in such quantity as to confer upon the rock a distinctly porphyritic character. In addition to the foregoing constituents, the quartz-dolerites contain as accessory ingredients hornblende, biotite, iron ores, and apatite. An ophitic structure is occasionally to be observed, but is in general not characteristic of rocks of this type.

The segregation veins are of two kinds, " blue bands " and " red bands ", the latter often coarser in texture, but apart from colour

[1] See Sir J. J. H. Teall, *British Petrography*, 1888, p. 190; also J. D. Falconer, *Trans. Roy. Soc. Edin.*, vol. xlv, 1906, p. 133; P. Macnair, *Trans. Geol. Soc. Glas.*, vol. xiii, 1907, p. 56; G. W. Tyrrell, Geol. Mag., 1909, pp. 299 and 359; Dr. J. S. Flett, *Mem. Geol. Surv. Scotland*, " The Geology of the Neighbourhood of Edinburgh," 1901, p. 301; and E. B. Bailey, *Mem. Geol. Surv. Scotland*, " The Geology of the Glasgow District," 1911, p. 146.

there does not appear to be any principle that could serve to discriminate them. Sometimes, either may consist of isolated crystals of acid plagioclase enclosed in a groundmass entirely of micropegmatite, ferromagnesian constituents being notably absent, or they again may be discerned simply as a mosaic of quartz and felspar, in part orthoclase, that encloses porphyritic crystals of oligoclase and oligoclase-andesine, micropegmatite occurring only as a frame round the latter and dying away into the surrounding granular aggregate. On the other hand, the characteristic intergrowth of quartz and felspar may be, and very often is, entirely absent. Long needles of augite often occur in these vein rocks, likewise shreds and larger fragments of hornblende and biotite. Chemically, the veins are distinguished by their higher content of silica and alkalies, showing at the same time a corresponding diminution in lime, magnesia, and iron. Petrographically, as pointed out by Dr. Flett, they are always cognate to the igneous rock-bodies in which they occur.

As regards the distribution of the quartz-dolerites in East Fife, it may be said that they lie west of a line drawn south from near Guard Bridge on the estuary of the River Eden to Leven on the Firth of Forth. East of this line the intrusions belong in general to the olivine-dolerites, but it must be clearly understood that this march is only intended to be approximate in its nature and applicable only to the area dealt with in the memoir.

Some of the quartz-dolerites attain a great size in East Fife. Thus the large sheet or sill that stretches south-west from near Wemyss Hall covers an area of approximately 3 square miles, and appears to be connected with another mass of no less extent farther to the south-west. It is this intrusion that has involved the outcrop of the Teuchats and Teasses limestone, and Sir Archibald Geikie has given a section showing how the latter and associated igneous rock have here probably been displaced by faulting. What relationship, if any, exists between the quartz-dolerite sills and the similarly occurring masses of olivine-dolerite is not clear from any field evidence in Fife known to the writer.

(*b*) *Olivine-dolerites.*—These rocks as developed in the area under review consist of felspar, monoclinic pyroxene, and olivine, along with subsidiary and varying quantities of magnetite, ilmenite, apatite, analcite, and zeolites. They appear as a rule to be in a fresher condition than the corresponding masses south of the Firth of Forth (e.g. the Gosford Bay dolerite), although rarely in East Fife can it be said indeed that the felspars are quite unaltered or the olivine without at least a film or sheath of serpentine.

In East Fife the best road-metals appear always to be obtainable from the olivine-dolerites. But in this connexion it may be stated that the freshest and most compact rocks do not always provide the most expedient sources of supply; for often the closest-grained and apparently most resistant masses are those specifically not

endowed with the qualities that experience has testified as best suited to the requirements of the engineer. Thus the rock of Kilbrackmont Craig, than which there is no fresher or more compact dolerite in East Fife, is not esteemed a first-class road-stone, and this is due to its smoothness of fracture. That appears to be a serious objection to its use, for it has been found that a road constructed with this metal suffers especially from the plucking action or suction of motor tyres. The units composing the surface rapidly become dislodged, and this can be attributed to a lack of frictional binding. Texture, therefore, must be regarded as a lithologic character of particular significance to the road surveyor. But in assessing the value of any rock as a medium for the repair and maintenance of roads, there are other factors bearing upon the matter to which also serious consideration must be given. One of these is the quality of brittleness, for it has frequently been observed that the same stone may endure differently, depending on the nature of the sole or foundation upon which it is superposed, and that what under certain conditions would furnish excellent setts or macadam, might be less suitable for the like purpose if departure be made therefrom.

Petrographically, the olivine-bearing dolerites of East Fife may be allocated to three principal types, viz. :—

(1) The Gathercauld type—an ophitic type.

(2) The Kilbrackmont and Baldutho type—a porphyritic type.

(3) The Kingask-Spalefield type—a picrite-teschenite type.

(1) *The Gathercauld type.*—The dolerite that furnishes material for a description of this type forms the large intrusion stretching south from Baldinnie to Gathercauld and terminating westwards in a finely columnar escarpment that has been noted by Sir Archibald Geikie. In hand specimen the rock is dark coloured, basic looking, fairly coarse-textured, and showing sometimes large crystals of pale yellow olivine. Microscopically, the mass consists of a framework or plexus of plagioclase laths, held together by ophitically related clumps of monoclinic pyroxene. In the interstices occurs another and later felspar, while throughout the whole and generally antecedent to the other minerals in an assumption of the solid phase are distributed olivine and accessory constituents. Along with the later felspar residual glass and analcite occur in small amount.

The felspar of the Gathercauld dolerite does not appear to be possessed of high refractive indices in any part of the rock. By optical means it can be determined that there is a range of plagioclase from labradorite, with from 60–65% of anorthite, through andesine to oligoclase and oligoclase-albite. (Note.—Very basic felspar does not seem to occur in any of the rocks under discussion; thus there is a quartz-dolerite exposed in a disused quarry at Lade Braes, St. Andrew's, the felspar of which is more anorthitic than in the case of any of the olivine-dolerites.) A brief

digression may here be permissible in reference to the determination of these acid plagioclases, and a method of examination indicated which the writer has found to yield valuable information. The optical dispersion of Canada balsam is greater than felspar, and by passing from the red to the blue end of the spectrum a fair range in refractive index can be obtained from the same medium. That is to say, supposing the field of the microscope to be illumined by red light the index of the balsam will be relatively low, but by a change in the character of the light the index can be readily increased. If therefore while one of these felspars is under observation the wave-length of the illuminant be progressively shortened, it is not difficult to see for what colour there is an agreement in the matter of refractive index.[1] The dispersion of the balsam and of the felspars being fairly well known, it is possible by such means to get a rapid and accurate indication of the nature of the latter. One of the first results obtained from an application of the above principle was a discernment of the fact that a lime-soda felspar may have adjacent lamellæ of very different composition, i.e. one lamella may perhaps be labradorite, those contiguous oligoclase. Such assemblages do not yield symmetrical extinctions in the zone normal to (010), and ordinarily would probably be neglected by the petrographer.

Reverting to the Gathercauld dolerite, it may be noted that the felspars enclosed by the pyroxene are labradorite, whereas the later-formed and interstitial felspar is acid plagioclase. It is interesting to observe the manner in which the latter frequently wraps round the terminations of the earlier product, and it is not uncommon to find a series of laths of more highly refracting labradorite enclosed in a felspathic medium of distinctly lower index.

The pyroxene is reddish or brownish in sections that show the characteristic prismatic cleavage, but in sections parallel to the crystal axis *c* is faintly purple and visibly pleochroic. The axis emerging upon the base, or more accurately between the bisectrix Z and *c*, is markedly dispersed ($r > v$) in the symmetry plane, but this dispersion cannot be observed so favourably in the case of the other axis owing to an increment in the angle Z—*c* with diminishing wave-length. It thus happens that in the same rock section axes may be found that are nearly "achromatic," others being strongly dispersed. A noteworthy point with reference to the pyroxene is that whereas it is ophitic towards the earlier felspar, it is sharply idiomorphic towards the later interstitial felspar.

Olivine is abundant in the rock of Gathercauld, frequently enclosed by pyroxene, or lying simply in a meshwork of felspar laths, but preserving its contour and rarely penetrated by the

[1] It is difficult with a spectroscopic illuminator to get a sufficient intensity of light: isolation of the lines of the mercury arc has been found to give useful results.

felspar. The accessory minerals include chestnut brown biotite, in ragged scales and plates, iron ores, analcite, apatite, and magnetite: there are also clumps of strongly birefringent zeolites.

Many sections of the rock are remarkably fresh, with the olivine traversed by only a few serpentinous cracks or enclosed in a film or sheath of serpentine. The best specimens are to be obtained from the escarpment or crag in the fields to the south of the quarry that has been opened in the north-western portion of the sill. As mapped, the intrusion extends east towards the Peat Inn–Baldinnie road, but the rock there exposed is a pyritiferous quartz-dolerite, and probably does not belong to the same mass.

The above rock may be regarded as a typical ophitic olivine-dolerite, and is of a kind that is not common in East Fife; indeed, the only other mass showing similar characters is that which occurs at Wilkieston, 5 miles to the south-west of St. Andrew's, which has been described in the Memoir. But here the rock is much less fresh, and shows a curious hypersthene-like weathering of its olivine. Also there is a large quantity of transfused chloritic matter.

(2) *Kilbrackmont and Baldutho type.*—Olivine-dolerites, of which the masses exposed at these localities may be taken as the type, are abundant in East Fife. The structure is not ophitic, as in the rock of Gathercauld, but in respect of their olivine content inclined to be porphyritic: that is to say, larger crystals of olivine lie in an environment of felspar laths and pyroxenes; the latter tending to occur as small idiomorphic prisms rather than as large plates. The rocks of Kilbrackmont and Baldutho are often beautifully fresh in section, and show large olivines, frequently with a marshalling of little idiomorphic pyroxenes round their margins; the avenues between adjacent crystals being somewhat more highly felspathic. Biotite, iron ores, apatite, and interstitial analcite occur as accessories.

The intrusions of the Denhead, Mount Melville, Gilston, Balcarres, and Kinaldy districts all belong generally to the above type of dolerite, though there are, of course, great variations in detail, and especially is that remark applicable to the matter of texture. Sometimes a flow or pseudo-flow structure may be observed, as in the small intrusion at Blindwells, near Largo. An especially fresh and interesting rock is that of Dunicher Law, east from the Backmuir of New Gilston. Here there is a high content of olivine and a tendency for the pyoxenes to segregate. The felspar is finely twinned on the albite and Carlsbad laws, and it is easy to make out that there is a range of plagioclase extending from labradorite through andesine to oligoclase, the first mentioned, of course, greatly predominating. Biotite occurs in small amount, and there is a little interstitial analcite. The Dunicher Law rock is interesting as affording a passage to the Kingask intrusion, mentioned below.

The masses of Mount Melville, Denork, and Drumcarrow may be described as coarser varieties of porphyritic olivine-dolerite.

These intrusions form marked topographic features to the south-west of St. Andrew's, especially the last mentioned, which rises into a tract of high ground over 600 feet above sea-level and that ranges westwards for over a mile to near Ladeddie. In the eastern part of this extent the mass is a non-ophitic olivine-dolerite, which, traced towards the west, greatly increases its content of iron-ores, interstitial glass also making its appearance. Followed still farther west the glass continues to increase in quantity until above Ladeddie the rock becomes a porphyritic olivine-basalt (this rock must not be confounded in the field with the basalt of the ash neck alongside). Some sections of this latter rock are remarkably fresh, and show a pale structureless glass, or one that is full of skeletal growths of iron ore, enclosing unaltered idiomorphic crystals of labradorite, also strongly dispersing purplish pyroxenes with green centres that often show hour glass structure and which are appreciably pleochroic. Larger crystals of olivine and pyroxene lie in the rock, conferring upon it a porphyritic habit.

The only other rock masses known to the writer in East Fife to contain such beautifully fresh glass as the above are those at the roadside at Gillingshill, and at Longside, to the north-west of Kennoway. But both these basalts, which mineralogically closely resemble the western Drumcarrow rock, occur as intrusions in volcanic necks, and this brings us immediately to the consideration of a matter of special interest, viz. the probable monomagmatic origin of the olivine-dolerites and vent basalts of the district. For if the apparent mineralogic relationship between these masses be a real relationship, and it appears real, then there is the probability that it has an important bearing on the question of the geological age of the volcanic vents of East Fife. The nature of this bearing may be indicated as follows: There is considerable ground for believing that the olivine-dolerites of East Fife represent merely the root system of the volcanic manifestations that were known to have occurred in this area in Upper Limestone times. If, as seems not unlikely, that opinion be correct, then the great sheeting and expansion of liquid igneous material that has taken place on or about the horizon of the Lower Limestones would find ready explanation as being connected with the depth of cover existing at that time. For any igneous protrusion ascending from depths must ultimately reach a height when by fluid pressure it will lift, or tend to lift, its roof. Should the strata be horizontal, then the conditions become eminently favourable for the production of great sheets. In the above instance it appears possible that the zone of partition and consequent insertion of igneous matter may have lain somewhere about the stratigraphic level of the Lower Limestones. But the introduction of any large volume of fluid igneous substance in the manner indicated, has serious implication, namely, that the rocks in the deeper part of the sequence would experience displacement and rupture, sedimentation meanwhile being in progress uninterruptedly

above. The effect at the surface of these phenomena would probably be warping of the sedimentation floor. Now a chief objection to any intra-Carboniferous allocation of the vents of East Fife has always been their apparent posteriority to the faulting or some of the faulting of the district. It will be clear that such considerations as the foregoing, if esteemed rational, sanction an extension of the time period within which the vents may fall, and the possibility ought not to be lost sight of that many of the necks of East Fife, as bearing some genetic relation to the sills,[1] really belong to the volcanic episode that was known to have formed part of the geological history of the Upper Limestones.

Special reference must now be made to the rocks of Crossgates, Radernie, and Lathones, as the masses to be seen at these localities afford types of igneous product not known to the writer elsewhere in Fife. The rock of Crossgates can be seen in a quarry on the east side of the main road that runs south from near Guard Bridge towards Colinsburgh. Reference to the published 1 inch geological map of the district will show that this road about 6 miles to the south-west of St. Andrew's passes the Peat Inn, but before actually reaching that locality as followed from the north, makes junction with another highway running north-west towards Ceres and Cupar. It is just a few yards north of this junction that the quarry referred to is situated. The Radernie mass is exposed in the fields to the north of the above quarry and again near the roadside. There appears a little uncertainty in the mapping at this part, and the probability is that the Radernie mass extends farther north than indicated. The Lathones mass is exposed some distance south of the main road that connects Peat Inn with Higham.

These three intrusive masses have been intruded into the Lower Limestones and coals of the Carboniferous Limestone Series, and they lie in an area that has been greatly folded and fractured. The Crossgates intrusion is a sheet or sill beneath which some of the lower coals of the district have been wrought, but the nature of the Radernie and Lathones masses is not clear from any field evidence at present available.

In the fields the rocks of Crossgates and Radernie are generally compact dark gray, often with a pinkish tinge, and having abundant and uniformly distributed dark spots. Along the north side of the Crossgates quarry a coarse-grained exceptionally tough pink rock occurs sporadically in veins and patches: this appears to be of the nature of segregation from the main mass of the rock. The Lathones rock in a hand specimen is not unlike some quartz-dolerite or dark-coloured diorite. It is more coarsely textured than the Crossgates material, and contains a considerable amount of some pink mineral.

[1] Daly, "Nature of Volcanic Action," *Proc. Amer. Acad. Arts. and Sci.*, vol. xlvii, 1911, remarks on the steady association of tuff neck and sill in the Scottish shires, and thinks that the former may perhaps be ascribed to gas emanations from the margins of the masses forming the intrusions.

Microscopically, the rocks of Crossgates and Radernie have clearly been porphyritic olivine-dolerites, and it is not very difficult to get a picture of the bulk of the original masses as having characters in many respects similar to the rocks of Kilbraekmont and Baldutho. That is to say, they consisted originally of an interwoven mass of elongated plagioclase crystals; this meshwork enclosing larger and idiomorphic olivines, numerous little idiomorphic prisms of monoclinic pyroxene, ilmenite, uniformly distributed in grotesque skeletal plates, abundant apatite needles, and dark-brown biotite. But the most profound change has dispersed this original mineral assemblage; the felspars have been dissipated and analcite in large measure taken their place. Every stage in the digestion and replacement of the original plagioclase can be followed under the microscope. Examined by the method of dark ground illumination, the amount of turbid pinkish analcite can be observed to great advantage. But not only does the analcite permeate all the fabric of the rock, it is also collected into ocelli that are often turbid in the centre and have a pellucid rim that is not uncommonly polygonal in outline. It is interesting to note that the introduction of the analcite has in no way disturbed the original disposition of the unaffected minerals such as the pyroxene. The best method of examining this curious rock is to turn the vibration traces of the nicols slightly aside from rectangularity of intersection so that a dark gray light fills the field of the microscope. The felspar ghosts in respect of the images they afford in the ocular then become easy to discriminate.

The veins and segregation patches of the Crossgates rock[1] consist of an open meshwork of plagioclase crystals with ophitically related purplish pyroxene, and there is an abundant interstitial highly felspathic (alkaline) residue. The felspars range from labradorite to andesine and oligoclase: generally they are much altered and replaced by analcite, (?) albite, and calcite. The pyroxene is more decidedly purple than in any rock noted so far in this paper; in this character indicating a relationship with the teschenites. Towards its margins the mineral becomes green tinted, or is sometimes bordered by an emerald green substance having different optical properties. As noted, the pyroxene is in part ophitic, but has sharp outlines where it abuts against the residuum. The latter is a turbid brown or reddish-brown aggregate, full of feathery growths of soda-rich felspar, patches of clear or cloudy analcite, shreds of intensely absorbing biotite, granules of iron ore, chlorite, abundant apatite, and a green mineral in flakes and hastate fragments which in respect of its strong birefringence, the negative character of its principal zone, and other optical properties is taken to be aegirine; also there are occasional

[1] Comparison of this material should be made with some of the rocks described by Mr. Tyrrell in his valuable paper, "The late Palæozoic Alkaline Igneous Rocks of the West of Scotland," GEOL. MAG., 1912, pp. 69 and 120.

smaller idiomorphic pyroxenes. Ilmenite in skeletal plates is an ingredient of early separation.

The Lathones rock microscopically is a reticulum of plagioclase felspars ranging as in the coarse variety of the Crossgates rock from oligoclase to labradorite. Some of the latter are earlier than the olivine, which the mass evidently contained, as pseudomorphs of this mineral are often to be seen penetrated by square-ended laths of labradorite. Pyroxene of a distinctly purplish hue with curious pale green borders, or sometimes entirely green, is an essential constituent, the mineral being ophitic towards much of the felspar and showing in favourable sections the dispersion usual in the olivine dolerites. Ilmenite, biotite, a little aegirine, and not inconspicuous interstitial orthoclase also occur: there is, too, another felspar of low refractive index, which being optically positive is probably albite.

The consolidation history of the Lathones rock has not been one continuous process, but there has been a period of resorption, for many of the felspars and pyroxenes show signs of corrosion and subsequent accretion. Secondary (?) albite, analcite, occurring primarily but also replacing orthoclase, and chlorite are distributed throughout. Many portions of the mass are full of little cavities bordered by orthoclase and filled with analcite and zeolites. Clearly the rock has been the subject of much alteration and change, but how much of this should be regarded as belonging to its initial thermal history and how much entirely secondary the writer is not prepared to say. The diabases of Crossgates, Radernie, and Lathones, it may be repeated, are not like any of the other olivine-bearing rocks of the district, and probably in respect of their more distinctly alkaline character should be relegated to the essexites. A more careful analysis of their characters is reserved to another time.[1]

(3) *Spalefield and Kingask type.*—The rock of Spalefield has long been known to geologists from the careful description of it given by Dr. Flett. Since that time the teschenites have been found to have a wide distribution in Central Scotland and to be remarkably uniform in their general mineralogical attributes. The distinguishing characters of these rocks are their abundance of analcite, their strongly dispersing purple pyroxene, and their intensely coloured hornblende. In addition to these constituents occur lime-soda felspar and accessory minerals, among which apatite is conspicuous. No example of a teschenite that has been observed by the writer could be described with confidence as being anything but a highly altered rock. Analcitic replacement of felspar has taken place on a great scale in these masses and, without derogation of the doctrine of the primary nature of some of the

[1] Dr. Peach recently informed me that many years ago in a traverse of this ground with Sir Archibald Geikie, they noticed these curious rocks; there is, however, no reference to them in the East Fife Memoir.

analcite, there is little doubt that the greater part of this mineral is entirely secondary. The teschenites of the Edinburgh district, of East Lothian, and of the Glasgow district, all bear abundant testimony to the accuracy of that opinion. Large tracts of usually turbid analcite in these rocks are simply the replacement products of plagioclase felspar, though perhaps only a parallel orientation of decomposition products along what formerly were cleavage cracks may remain to mark the one-time presence of that mineral. The teschenites are in some respects noteworthy for the capricious disposition of their constituents, for the same mass will often show highly analcitic areas or, again, parts that are richer in hornblende, pyroxene, or biotite, and this without any large scale differentiation of the mass in situ.

The Spalefield teschenite is interesting on account of its beautifully fresh olivine. In the southern portion of the quarry in which the rock is exposed, a more highly felspathic variety can be collected. Occasionally large areas of turbid analcite enclose partially replaced felspar, that is albite-oligoclase: it is probably this mineral that Dr. Flett commented upon as having a deceptive resemblance to nepheline.

The rock of Kingask may be referred to here, though it is neither a typical teschenite nor a typical picrite. But it has affinities with both. The quarry where the mass is exposed is situated about 3 miles to the east of St. Andrew's on the north side of the main road that runs to Crail. The rock weathers spheroidally, and is in places highly decomposed. On the south-east side of the exposure the igneous mass is seen to make junction with sandy sediments that have been highly altered and in places partly recrystallized. The intrusion appears to have been initially at a high temperature, and in one place a number of small spheroids of sediment were noted in the igneous rock apparently in process of digestion. The rock is extremely hard and has a first-class reputation as a road-stone, being durable and an excellent " binder ".

Microscopically, the rock can be seen to have a high content of olivine, sometimes completely in the condition of serpentine, frequently remarkably fresh and unchanged. Analcite is abundant in pellucid patches, but often turbid and replacing plagioclase felspar; the latter showing the usual range present in the olivine-dolerites. Purplish and brownish pyroxene is an essential ingredient of the rock, the crystals having a good development of the front and back pinakoids, being elongated parallel to the crystal axis *c* and generally idiomorphic except where abutting against olivine. The subordinate constituents include apatite, magnetite, biotite, and zeolites. Where the rock makes contact with the sediments, a more teschenitic facies is taken on, much richer in biotite and resembling in striking fashion some portions of the rock of Spalefield.

These fragmentary notes may be concluded with an expression of the hope that some systematic investigation may at no distant

date be undertaken among the dolerites of Fifeshire. For the relationship of these masses—both quartz- and olivine-bearing types—to the plication and fracturing of the associated sedimentary rocks, and the discovery, if possible, of their connexion with the ash necks of the district; also a consideration of whatever evidence they may afford bearing upon the general problems of igneous intrusion, are all matters deserving of careful study. It is therefore satisfactory to record that in the midst of the actual field providing these interesting and promising subjects of research, the teaching of geology has been resumed in the old University of St. Andrew's.

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## A Cambro-Ordovician Section in the Beaverfoot Range, near Golden, British Columbia.

By Lancaster D. Burling.

§ 1. The Beaverfoot Range lies immediately to the east of the Rocky Mountain Trench, and is the westernmost of the ranges included in the Rocky Mountain system.

The first geologist to study this section was McConnell, who published in 1887 [1] a report on the geology along the newly completed mountain section of the Canadian Pacific Railway. The broader features of the striking overturn which affects the entire Beaverfoot Range were described, fossils were found in both the stratigraphically underlying "Graptolite Shales" and the stratigraphically overlying "Halysites Beds", and a cross-section was given showing the overturned nature of the rocks composing the Beaverfoot Range.

§ 2. The present paper offers new data regarding the stratigraphy of the upper part of the Cambrian and the Ordovician section in the Beaverfoot Range. Two new formation names are proposed: Glenogle Shales for the "Graptolite Shales" (see §§ 5, 8, and 12), and Beaverfoot Formation for the "Halysites Beds" (see §§ 4 and 7). There are also presented detailed sections of the Glenogle shales (§§ 5 and 14) and the overlying Beaverfoot Formation (§ 4), with reference to the fossil horizons secured. There is a short discussion of the Goodsir Formation, which is shown to be partly of Cambrian age (see § 16), and there is a generalized table correlating the rocks exposed in the Beaverfoot Range with those exposed in Mount Bosworth on the continental divide, 25 miles to the east (see § 17).

§ 3. The section was measured in the summit of the range (where it is crossed by the Whiskey Trail), overlooking the Columbia Valley at Mons on the Kootenay Central Railway, about 15 miles south-east of Golden, British Columbia, and is as follows:—

[1] *Ann. Rep. Geol. and Nat. Hist. Surv. Canada*, 1887, Part D, pp. 1–41.

*Section of Ordovician Strata in the Beaverfoot Range.*

| | | ft. |
|---|---|---|
| § 4. | BEAVERFOOT FORMATION (Ordovician: Richmond). | |
| 1. | Blue limestone alternating with 1 inch bands of black chert | 150 |
| 2. | Blue-grey massive limestones . . . . . | + 500 |
| 3. | Massive grey-blue cherty limestone . . . . . | + 25 |
| 4. | Massive dirty-grey-weathering blue limestone . . . | 100 |
| 5. | Lighter-grey-weathering (than 4) grey-blue limestone . | 20 |
| | 10 feet below top, Locality 15 : 109. | |
| | 20 „ „ „ 15 : 110. | |
| 6. | Little more thin-bedded but same as 5 . . . . . | 25 |
| 7 | Little more massive and with many chert nodules, rounded and banana shaped, etc. . . . . | 22 |
| | Near base, Locality 15 : 111. | |
| 8. | Light-dirty-grey more or less thin-bedded limestone alternating with zones 2 to 12 feet thick of very thin-bedded almost shaly limestone . . . . . | 75 |
| | 25–40 feet below top, Locality 15 : 112. | |
| | 50 „ „ „ 15 : 113. | |
| | 65 „ „ „ 15 : 114. | |
| 9. | Black shale . . . . . | 7 |
| 10. | White quartzite (not measured). | |
| 11. | Dirty brown to reddish-brown sandy shales in layers ¼ to 1 inch in thickness, weathers reddish near base . | 75 |
| 12. | These (11) pass imperceptibly into an arenaceous bandy weathering shale, poorly exposed but slope so marked would appear to accommodate about 700 feet of beds. One-fourth mile to the south the lower half of 12 is sandy to reddish-weathering, the upper half a dark-brown . . . . . | + 700 |
| 13. | Fairly massive, white, grey, and pinkish quartzite . . | 150 |
| § 5. | GLENOGLE SHALES (Ordovician: Chazyan at the top, Canadian at the bottom). | |
| 14. | Shales, arenaceous, light-brown, cover slope from here to top of ridge. Room for about . . . . . | 500 |
| | Near base, Locality 15 : 107. | |
| 15. | Series of one-foot-thick blue limestone beds with several feet of black shale between; the lower 10 feet composed of a cherty black shaly limestone . . . | 100 |
| 16. | Black shale, forming a prominent scarp in the slope due to being backed by the lower part of 15 . . . | 20 |
| 17. | Brown shale . . . . . | 10 |
| 18. | Thin-bedded blue limestone (alternating blue and grey striped on cross surfaces) with bedding faces weathering grey and each separated by ¼ to ⅛ inch slabs of grey limestone . . . . . | 35 |
| 19. | Blue-black shale with graptolite fragments . . . | 25 |
| 20. | More or less thin-bedded blue limestone . . . . | + 100 |
| | About half-way up in this and just below a 3 to 5 foot bed of black shale found. Locality 15 : 108 (of Canadian age), which is to be compared with Glenogle Brook fossils and with Locality 19 : 53. | |
| § 6. | GOODSIR FORMATION (Upper Cambrian at the base, passing up into Ordovician). | |
| 21. | Pearl-grey to bluish micaceous shale series, forming centre of range. | |
| | Base of measured section. | |
| | A few hundred yards along the strike to the west the section has the following fossil horizons :— | |

BEAVERFOOT FORMATION (quartzite portion).
GLENOGLE SHALES—
With graptolites, Locality 19 : 50 = Chazyan.
Fossils at base, Locality 19 : 53 (compare with 15 : 108) = Canadian.
GOODSIR FORMATION—
At top, Locality 19 : 51.
25 feet below, Locality 19 : 52.

### § 7. *Beaverfoot Formation* ("*Halysites Beds*").

McConnell [1] refers the "Halysites Beds" to the Silurian, recording the presence of *Halysites catenulatus*, *Favosites*, *Zaphrentis* ?, and some badly preserved gastropods, and this reference has been accepted by subsequent writers. In 1913 Allan [2] records the close resemblance of the "Halysites Beds" to the Intermediate limestones (Devonian), near Banff, but he leaves them in the Silurian.

At the meeting of the Geological Society of America in the winter of 1915–16, the writer exhibited fossils from these "Halysites Beds", and presented a short communication [3] announcing their correlation with the Richmond, a reference which was confirmed by those who examined the fossils. This was the first recorded identification of Richmond fossils in the Canadian Cordillera, and, curiously enough, the fossils secured included one specimen of *Beatricea* almost identical with one of the *Beatriceas* from the nearest previously known Canadian Richmond—Stony Mountain, near Winnipeg, Manitoba.

The beds to which the term "Halysites Beds" have been applied are in this paper called the Beaverfoot Formation from their typical exposure in the crest of the Beaverfoot Range above Mons, which is on the Kootenay Central Railroad, 15 miles south of Golden, British Columbia. Reference to the section (§ 4) will show that the formation is separable lithologically into two portions; (1) the cherty limestone series forming the exposed top (Beds 1–9 of the section), and (2) the quartzitic series forming the base (Beds 10–13 of the section). Only the upper portion, which becomes increasingly thin-bedded and shaly as one goes down in the section, has so far proven fossiliferous, and is referred to the Richmond. The lower portion, arenaceous shales and quartzites, may prove separable from the formation.

### § 8. *Glenogle* ("*Graptolite*") *Shales.*

The first mention of the graptolite shales is by McConnell in 1887,[4] who says: "Easily accessible sections of the graptolite shales close to the railway may be found in the bed of a small stream which joins the Wapta from the north about half-way between Palliser

[1] *Ann. Rep. Geol. and Nat. Hist. Surv. Canada*, 1887, Part D, p. 22D.
[2] *Summary Rep. Geol. Survey, Canada*, for 1912, p. 172, 1913.
[3] Burling, *Bull. Geol. Soc. America*, vol. xxvii, 1916, p. 158.
[4] *Ann. Rep. Geol. and Nat. Hist. Surv. Canada*, 1887, Part D, p. 23D.

and Golden City." The exact locality is in the bed of the creek, just west of Glenogle, a way-station about 7 miles east of Golden.

The Graptolite Shales at this point were discovered by McConnell [1] in his study of the section along the 51st parallel. The graptolites were turned over to Lapworth, who contributed a note regarding their identification and correlation, which was embodied in McConnell's report. The locality was correctly described by McConnell, but Lapworth's note made the mistake of listing the fauna as occurring at "Kicking Horse (Wapta) Pass", and this error has been perpetuated in all subsequent references to the fauna. There are no rocks younger than the lower part of the Upper Cambrian at Kicking Horse Pass, and the latter locality is about 25 miles in a direct line north-east of the locality from which the graptolites were secured. Along the right-of-way the distance is even greater, rising to 45 miles.

§ 9. Lapworth [2] identified the following species :—

*Didymograptus* n.sp. (cf. *D. euodus* Lapworth).
*Glossograptus ciliatus* Emmons.
*G. spinulosus* (Hall) [ =*Glossograptus ciliatus* Emmons].[3]
*Cryptograptus tricornis* (Carruthers).
*Diplograptus angustifolius* Hall [= *Diplograptus* (*Glyptograptus*) *angustifolius* (Hall)].
*D. rugosus* Emmons [= *Diplograptus foliaceus* (Murchison)].
*Climacograptus caelatus* Lapworth [= *Climacograptus antiquus* Lapworth].
*Phyllograptus* or *Lasiograptus* sp.

Lapworth [4] referred the fossils from Glenogle [5] to the "age of the Utica slate, or, at any rate, to the Trenton-Utica fauna of the United States and Canada", and suggested that they might be a little older than the Normanskill fauna. In 1889 Lapworth [6] describes a graptolite fauna collected by Dawson on Dease River as identical with the one previously described from Glenogle and confirms his previous determination as to their being a little older than the Normanskill, but places them in the Black River-Trenton instead of the Utica or the Trenton-Utica.

§ 10. Gurley [7] places both faunas in the Chazy in the following words : "Somewhere between the *Dichograpsus* fauna, characteristic of the Calciferous, and the *Dicellograpsus* fauna, characteristic of the (certainly pre-Utican and probably) Trenton, are to be placed the faunas" occurring at Glenogle and on the Dease River.

[1] *Ann. Rep. Geol. and Nat. Hist. Surv. Canada*, 1887, pp. 22D–24D.
[2] Id., p. 23*d* ; and *Science*, vol. ix, 1887, p. 230.
[3] Corrections after Bassler, *Bull. U.S. Nat. Mus.*, No. 92, 1915.
[4] *Ann. Rep. Geol. and Nat. Hist. Surv. Canada*, 1887, pp. 22D–24D.
[5] In the literature as Kicking Horse Pass, which is a locality 25 miles to the north-east.
[6] *Can. Rec. Sci.*, vol. iii, 1889, pp. 141–2.
[7] *Journ. Geol.*, vol. iv, 1896, p. 304.

" Approximately at least, these beds are of the same age, and in a general way, and as a diagnosis by exclusion, may be said to be Chazy."

§ 11. Ruedemann [1] believes that this reference places too much emphasis on differences in faunal composition, and states that both faunas " cannot be far removed from early Trenton age ". Later on in the same report,[2] he says : " In all of these places *Didymograptus sagitticaulis* occurs in the same horizon (*Dicellograptus* zone) as at the Normanskill, with the exception perhaps of the Dease River locality."

Allan [3] describes the graptolite shales as occurring in two infolded bands in the Beaverfoot Range. He says : " The thickness of these beds varies, and the lower contact is ill-defined, but there are at least 1,700 feet of black fissile shales, many beds of which contain graptolites."

The latest reference to the age of these shales is by Bassler,[4] who refers to them as Chazyan (Normanskill).

§ 12. The fact that we have now secured data as to the relations of the " graptolite shales " to the overlying formation, together with palæontological evidence as to the age of the beds immediately below, leads me to the conclusion that they should be named ;[5] and since they were first found at Glenogle, and are there represented by the most fossiliferous beds yet discovered, it would seem appropriate that they be called the Glenogle shales. Such a name will also call attention to their geographic position, a feature of importance, since they are nowhere listed as occurring at Glenogle but at a locality (Kicking Horse Pass) 25 miles away. The formation is stated by Allan [3] to be at least 1,700 feet thick. Though he does not say so, this figure is probably based upon measurements at Glenogle. It appears to have a thickness of 700 feet in the summit of the range 10 miles south of Glenogle. The type locality is at Glenogle, in the first creek west of the station, and in the adjacent rock-cut in particular. The lower (Canadian) portion of the formation can be studied in the bed of the first creek east of Glenogle, and the overlying beds can be studied in the high summits to the south. Near Glenogle the relations are destroyed by the presence, between the two formations, of the Kicking Horse River.

The railroad track here follows the north bank of the Kicking Horse (Wapta) River, which has cut its canyon between a series of very steeply inclined shales and a series of massive white weathering quartzite beds whose dip-slope forms the southern side of the valley.

The geological structure is that of a large overturn, and the shales north of the river really underlie the massive beds across the river to

[1] *Mem. New York State Musuem*, No. 11, pt. ii, 1908, footnote p. 25.
[2] Id., p. 251.
[3] *Summ. Rep. Geol. Surv. Canada for* 1912, 1913, p. 172.
[4] *Bull. U.S. Nat. Mus.*, No. 92, 1915, p. 550, etc.
[5] See Burling, Abstract, *Bull. Geol. Soc. America*, vol. xxxii, 1921, p. 128.

the south, which they appear to rest upon. Locally, however, the attitude of the beds is so variable that it is quite possible for particular minor sections to occupy their normal relations.

§ 13. The general locality was visited by Charles D. Walcott and the writer in 1909, when we secured specimens of the *Obolus* listed in § 14. In a second visit to the locality the writer spent some time in collecting from the graptolite horizons exposed in the stream bed just west of the station (probably the one referred to by McConnell) and in the railway cut between that stream and the station, and in measuring and collecting from the section of *Obolus*-bearing shales and limestones exposed in the bed of a stream which is spanned by a masonry bridge a few hundred yards east of the station at Glenogle. We shall use the term Glenogle Creek for this stream.

The beds outcropping in Glenogle Creek strike north-west–south-east, and dip almost vertically (thus differing by 60 to 70 degrees from the dip of the massive beds which overlie them), and they occur stratigraphically below an exposure of the graptolite-bearing shale in the small cutting just east of the masonry bridge.

The Glenogle Creek section is exposed in the bed of the creek, and outcrops on the east side of the creek between the masonry bridge and the mouth of the canyon. It may be described as follows :—

§ 14. *Glenogle Creek Section.*

Top (East) :—

| | | |
|---|---|---|
| 1. | Covered by railroad grade, in which there is a cutting exposing graptolite shales, and the Kicking Horse River. | |
| 2. | Fairly massive light-blue limestone, slightly mottled and weathering to a dirty grey . . . . . | 2 ft. |
| 3. | Thick-bedded dark-blue limestone, considerably sheared, with some layers of blue shale . . . . . | 3 ft. |
| 4. | Blue limestone in bands 1–3 inches thick with intercalated blue shale bands an inch or more in thickness . . | 4 ft. |
| 5. | Massive band of dark-blue limestone . . . . . Fossils in upper 4 inches which weathers slightly yellowish. Locality No. 1. | 16 in. |
| 6. | Blue shale . . . . . | 3 in |
| 7. | Blue limestone . . . . . Fossils in upper 4 inches which weathers slightly yellowish. Locality No. 5 (*Obolus*, etc.) | 6 in. |
| 8. | Thin-bedded blue limestone and shale similar to 4 . . Fossils 8 feet above base, Locality No. 2. Fossils 6 feet above base, Locality No. 3. | 12 ft. |
| 9. | Fairly massive-bedded blue limestone . . . . Fossils in upper 4 inches, Locality No. 4. | 1 ft. |
| 10. | Cleaved shales . . . . . | 1 ft. |
| 11. | Covered . . . . . | + 25 ft. |
| 12. | Grey, blue, and black shales, sheared, exposed in gorge above the bridge. | |

This section should be compared with that portion of the section measured in the summit of the Beaverfoot Range (§ 5), which underlies the graptolites of bed No. 19.

§ 15. Allan [1] speaks of the conformable relations of the Goodsir to the overlying graptolite shales, and so far as the writer has been able to determine in the field there is no evidence of unconformity at either the upper or the lower boundaries of the Glenogle shale. In fact, where the graptolite-carrying portion of the Glenogle shales is exposed in observable relations to the overlying and underlying rocks (see the Beaverfoot Range section between §§ 6 and 7) there appears to be only one reason for making a separation between the graptolite shales (19 : 50) and the lower beds which carry the Glenogle Creek fauna (15 : 108 and 19 : 53). This is the fact that the graptolite shales are of Chazyan age and the Glenogle Creek fauna appears to be Bretonian and therefore to be assigned to the Canadian. But Allan's definition of the Goodsir (6,000 feet) as underlying the graptolite shales hardly justifies us in referring to it the palæontologically identifiable series of Canadian beds which underlie the Chazyan graptolite shales. We have, therefore, included bed No. 20 of the section with beds Nos. 14 to 19, as forming part of the Glenogle shales (see § 5).

## § 16. *Goodsir Formation.*

The Goodsir formation was described [2] from the Ottertail Range, a few miles to the north, but it is exposed in its typical manner in the Beaverfoot Range. Here, as in the Ottertail Range, it carries abundant fossils, and these range upward in age from the so-called "*Ceratopyge* fauna" of Walcott [3] at the base. As announced in 1916,[4] these fossils are to be compared, not with *Ceratopyge*, but with forms from the Orr formation of the Upper Cambrian in the House Range of Utah. The line between the Cambrian and the Ozarkian is, at least, tentatively drawn by Ulrich [5] at the top of the Orr formation; and the base of the Goodsir thus lies well down in the Upper Cambrian, as that term was used by Walcott.

The middle and upper portions of the Goodsir formation have yielded a number of fossil horizons, which will fill in that portion of the geological column between the Upper Cambrian and the Canadian, but the writer was unable in the field to locate stratigraphic evidence for the true position within the formation of the Cambro-Ordovician boundary.

## § 17. *Correlation Table.*

There is presented herewith a generalized table correlating the succession in the Beaverfoot Range and in Mount Bosworth :—

[1] *Mem. Geol. Surv. Canada*, No. 55, 1914, p. 101.
[2] Allan, *Summ. Rep. Geol. Surv. Canada for* 1912, 1913, p. 172.
[3] *Smithsonian Misc. Coll.*, vol. lvii, No. 7, 1912, pp. 233–4, pl. xxxv.
[4] Burling, *Summ. Rep. Geol. Surv. Canada for* 1915, 1916, pp. 98–9.
[5] *Bull. Soc. Geol. America*, vol. xxii, 1911, p. 612.

| Beaverfoot Range. | Mount Bosworth. |
|---|---|
| Exposed top. Beaverfoot formation ("Halysites limestone") of Richmond age (1).[1] | |
| Glenogle shales ("Graptolite shales") of Chazyan (Normanskill) age, with shales of Canadian age (2) [1] immediately below and almost inseparable from them. | |
| Goodsir shales ranging in age from Canadian or pre-Canadian at the top to true Upper Cambrian (that is, lower than Ozarkian) at the base (3) [1] ± 6,040 feet (Allan). | |
| Ottertail limestone of Upper Cambrian age ± 1,725 feet (Allan). | |
| Chancellor formation of Upper Cambrian age ± 4,500 feet (Allan). | |
| | Exposed top (4).[1] |
| | Sherbrooke formation of Upper Cambrian age (5).[1] |
| | Paget formation of Upper Cambrian age. |
| | Bosworth formation of Upper Cambrian age (6).[1] |
| | Eldon formation of Middle Cambrian age. |
| | Stephen formation of Middle Cambrian age (7).[1] |
| | Cathedral formation of Middle Cambrian age. |
| | Mount Whyte formation of Middle Cambrian age (8).[1] |
| | Lower Cambrian. |

*Notes on the Correlation Table.*

(1) The change in the reference of these beds from Silurian to Richmond is discussed in this paper, § 7.

(2) The inclusion of both the Normanskill and the Canadian horizons within the limits of the Glenogle shales is discussed in this paper, § 15.

(3) The Upper Cambrian horizon at the base is the one carrying the fossils described by Walcott as "Ceratopyge". The change in the systemic reference of this fauna is discussed in this paper, § 16.

(4) The relations of the Chancellor formation at the base of the section in the Beaverfoot and Ottertail Ranges to the Sherbrooke formation in Mount Bosworth and Mount Dennis are difficult of determination. The base of the Chancellor formation itself is described by Allan [2] as consisting of "highly sheared grey shales, slates, argillites, and phyllites". These outcrop in the valleys where erosion has exposed them and are estimated to be 4,500 feet thick, but while several of the mountains expose the Sherbrooke formation in their summits, the relations to the overlying Chancellor shale series has not been observed.

[1] These numbers refer to the notes which follow.

[2] *Summ. Rep. Geol. Surv. Canada for* 1912, 1913, p. 168.

(5) The Mount Bosworth section was first described [1] as overlain by the Ordovician, but a later visit[2] proved the presence in the uppermost beds of Cambrian fossils and true Ordovician was placed several thousand feet higher in the section.[3]

(6) The Bosworth formation is of special interest as the locus of the earliest discovered evidence of profound disconformity between the Middle Cambrian and the Upper Cambrian. The contact between the Middle Cambrian Eldon and the overlying Bosworth with its ripple marks, mud cracks, and casts of salt crystals has been described.[4] Since these papers were written the Bosworth has been identified in the Sawback Range, west of Banff, and in the vicinity of White Man's Pass, south of Mount Assiniboine, in each of which localities it preserves its peculiarities of sedimentation and character.

(7) The Stephen formation is the horizon which has yielded the remarkable *Oggopsis* shale and Burgess shale faunas, assemblages which occupy very fine-grained lenses within its boundaries in Mounts Stephen and Field respectively. As has already been described,[5] the formation loses this fine-grained character as it is followed eastward, and in Castle Mountain, just west of the Sawback Range, it is coarsely ripple-marked and mud-cracked. It may very well be absent as a formation in the Sawback Range.

(8) This is the formation carrying the *Albertella* fauna, whose stratigraphic position has finally become established,[6] and whose fauna has been figured.[7] It will be of interest to record here that as the *Albertella* shale is followed southward past Mount Temple into the Mount Assiniboine region, and northward into the Mount Robson region, it becomes progressively more calcareous, and that at Mount Robson and Mount Assiniboine the horizon is represented by a calcareous *Albertella* horizon in the general limestone shale section of the Middle Cambrian.

Dr. Walcott believes [8] that the "stratigraphic position of the Mount Whyte justifies its classification with the Lower Cambrian", and, I believe, that the stratigraphic relations [9] near the base of the formation justify the transfer of its major and upper portion to the Middle Cambrian. Wherever the line is drawn we both seem to be

[1] Walcott, *Smithsonian Misc. Coll.*, vol. liii, No. 5, 1908, p. 204.

[2] Allan and Burling, Walcott, id., vol. lvii, No. 7, 1912, p. 229.

[3] Allan, *Summ. Rep. Geol. Surv. Canada for* 1911, 1912, pp. 171–81; Burling, *Journ. Washington Acad. Sci.*, vol. ii, 1912, p. 357.

[4] Burling, "Shallow Water Deposition in the Cambrian of the Canadian Cordillera": *Ottawa Naturalist*, vol. xxix, 1915, pp. 87–8; "Down-warping along Joint Planes at the Close of the Niagaran and Acadian": *Journ. Geol.*, vol. xxv, 1917, pp. 145–9.

[5] Burling, *Ottawa Naturalist*, vol. xxix, 1915, pp. 87–8.

[6] Burling, "The Albertella Fauna Located in the Middle Cambrian of British Columbia and Alberta": *Amer. Journ. Sci.*, vol. xlii, 1916, pp. 469–72.

[7] Walcott, "Fauna of the Mount Whyte Formation": *Smithsonian Misc. Coll.*, vol. lxvii, No. 3, 1917, pp. 61–114.

[8] *Science*, vol. xlv, 1907, p. 355.

[9] *Summ. Rep. Geol. Surv. Canada for* 1915, 1916, p. 100.

agreed that the Lower-Middle Cambrian boundary can be determined by a study of the stratigraphy. Since the broader stratigraphy of a given bed is not so much a matter of opinion as of observation, the only inference that can be drawn is that there are breaks of more or less magnitude at both the top and bottom of the formation. In interpreting these Dr. Walcott refuses to admit the possibility of the recurrence in Middle Cambrian time of surviving remnants of the Mesonacidae; the writer sees in the sudden introduction of new forms evidence far more dependable than the ultimate extinction of the old.

## On the Occurrence of *Daviesiella llangollensis* (Dav.) in Derbyshire.

By J. Wilfrid Jackson, M.Sc., F.G.S., Assistant Keeper, Manchester Museum.

THE object of this paper is to deal more fully with the occurrence of *Daviesiella llangollensis* (Dav.) in the Carboniferous Limestone of Derbyshire,[1] and further to make some observations on the sequence in the Midland area. In a later paper I hope to deal with the horizon of the "Brachiopod Beds".

*D. llangollensis* was first noticed by me when making a traverse of the type-section between Miller's Dale and Buxton some years ago, but at the time fragmentary specimens only were obtained. These were tentatively referred to the species and placed on one side awaiting more perfect material. On subsequent visits I obtained numerous specimens, which proved to be quite typical of the species in question.

The locality where *D. llangollensis* occurs is situated in Wye Dale, immediately at the foot of Topley Pike, about 3 miles east of Buxton. The beds containing it are exposed in a small roadside quarry at the entrance to Deep Dale, and consist mainly of well-bedded, dark-coloured limestones, dolomitized in part. Some hard, black, calcareous shale is also present.

The species is most abundant in the bed forming the floor of the quarry, and in the dolomitic bed immediately above, but it continues sporadically through some of the overlying limestones. Up to the present its vertical extent has not been ascertained.

Several other fossils are present in these beds, but their imperfect nature renders identification somewhat difficult. The following, however, have been recognized: *Syringopora* sp., *Lithostrotion martini* (broken corallites), *Seminula* cf. *ambigua* (or *globularis*), and *Bellerophon* sp. (imperfect cast).

The *Daviesiella* beds form part of the lowest limestones visible in the typical east-west section of Dr. T. F. Sibly.[2] They are

[1] See record in Geol. Mag., Vol. LIX, 1922, p. 335.

[2] Sibly, "Faunal Succession in the Carboniferous Limestone (Upper Avonian) of the Midland Area": *Q.J.G.S.*, vol. lxiv, 1908, pp. 34–82.

strikingly distinct from the massive white limestone—the Chee Tor Rock—forming the summit of Topley Pike, and are probably part of the limestones marked 8 in the Geological Survey Memoir.[1] A fault, with a small downthrow to the south, is present immediately to the south of the section. The beds are also seen in the large (upper) quarry to the west, but I have not examined these in detail.

The presence in the Manchester Museum of Davidson's type-specimens of this species has enabled me to compare critically the Topley Pike examples. Davidson's types were presented to the Museum many years ago by G. W. Ormerod, and were figured first in the *Quarterly Journal of the Geological Society*, vol. x, 1854, and later in the Monograph of British Fossil Brachiopoda (Palæontographical Society), vol. ii, 1860. In the first publication three specimens [L9834, L9836, and L9837][2] are figured on pl. 8 (figs. 7, 8, and 2-3) from Treflach Wood, at Trefonen, south-west of Oswestry; one specimen [L9835] from the beach at Beaumaris, collected by Henry Ormerod (pl. 8, fig. 6); and one specimen [L9838] from Tidenham Chase (pl. 8, fig. 5), the figures in all cases being reversed. In the second publication all the specimens, except L9834, are re-figured the right way on pl. xlv, but with a somewhat different legend in two cases, as follows: L9836 (= fig. 4), Llanymynech; L9837 (= figs. 1–2), Trefonen; L9835 (= fig. 3), Llanymynech; L9838 (= fig. 6), Tidenham Chase.

The Topley Pike specimens agree in every way with the above specimens, both externally and internally. The fine, thread-like, costation is very distinctive of the species, as well as the rows of close-set pits along the furrows, when the outer layer of shell is removed. But the most characteristic features are the narrow area, and teeth in the ventral valve, and the remarkable convexity and prominent bulging umbo. In most of the specimens the ventral valve is of extraordinary thickness. When seen *in situ* the species might be mistaken, at first glance, for a finely ribbed *Productus giganteus*, but a close examination, especially if the hinge is visible, will at once reveal the difference.

*D. comoides* (Sow.) differs from the present species by the possession of a much deeper area, and, in consequence, a more visible delthyrium. The umbonal region is also more depressed.[3]

*D. llangollensis* is probably the species referred to in some lists as *Chonetes* cf. *comoides*, at least in part.

The occurrence of *D. llangollensis* in the Midland area is of considerable interest on account of the presence of the species in the limestones overlying the basement-conglomerate of the Carboniferous Limestone in parts of the North Wales area, the

[1] *The Carboniferous Limestone, etc., of North Derbyshire*, 2nd ed. (1887), p. 18.

[2] Numbers in square brackets are the registered numbers in the Manchester Museum.

[3] Cf. Davidson, *Monog. Brit. Foss. Brach.*, ii, 1860, pl. 45, fig. 7, with pl. 45, figs. 1–6; and pl. 55, figs. 6–8 ( = types of *comoides*), with pl. 55, fig. 9.

horizon of these limestones being regarded by the late Dr. Wheelton Hind and Mr. J. T. Stobbs as the upper portion of the *Seminula* Zone (= $S_2$).[1]

It will be recalled that Dr. Sibly, in his paper on the Faunal Succession of the Midland Area,[2] remarks that the North Wales limestones containing *D. llangollensis* must be regarded as of lower horizon than any beds seen in the typical section of the Midland area. It is probable that when Dr. Sibly was studying this section some 15 or 16 years ago, the little roadside quarry containing *D. llangollensis* may not have been opened.

The question of the horizon of the *D. llangollensis* Beds calls for some discussion, in which it will be necessary to review the records of the occurrence of the species in different areas.

The Topley Pike limestones were included by Dr. Sibly in the lower portion of the series correlated with the *Dibunophyllum θ* sub-zone (= $D_1$) of the South-Western Province. The presence of *D. llangollensis,* however, suggests that the limestones containing it should now be transferred to a lower horizon, viz. the *Seminula* Zone.

It is important to note that one of Davidson's types of this species (Dav. Monog., pl. xlv, fig. 6) comes from Tidenham Chase, $1\frac{3}{4}$ miles north-east of Chepstow, Gloucestershire. The original specimen is in the Manchester Museum (Registered No. L9838). It agrees in every way with the other examples from the Oswestry district figured by Davidson (pl. xlv, figs. 1–4), and was used by him to illustrate the enormous thickening of the ventral valve. The small amount of matrix between the two valves consists of dolomitic limestone.

This occurrence of the species in the South-Western Province has apparently been overlooked, as I can find no reference to it in any of the numerous papers on the correlation of the Carboniferous Limestone.

With regard to the horizons represented in the Carboniferous Limestone around Chepstow, the late Dr. A. Vaughan gives an outline of the sequence in this area, and a correlation of this sequence with the Avonian of Bristol.[3] From this outline it appears that the following zones are represented: $K_1$, $Z_1$, $Z_2$; above the latter level there is a lack of exposures and the next higher beds met with belong to the *Seminula* Zone. For some distance above the $Z_1$ level the beds are extensively dolomitized. As in the Bristol area, the *Seminula* Zone is thick, and contains the typical assemblage of fossils. Dr. Vaughan found no trace of the *Dibunophyllum* Zone. Unfortunately he gives no list of the Chepstow fossils.

[1] Hind & Stobbs, "The Carboniferous Succession below the Coal-Measures in North Shropshire, Denbighshire, and Flintshire": Geol. Mag., 1906, pp. 385–400, 445–59, and 496–507.

[2] Sibly, op. cit., 1908, p. 76.

[3] *Q.J.G.S.*, vol. lxi, 1905, p. 251.

In the Mitcheldean district, further to the north-east, extensive dolomitization occurs at the same level and continues upwards through the *Syringothyris* Zone (= C.).

No further information concerning the Chepstow area seems to be available, and the only suggestion that can be made is that the *Daviesiella* in question came from some portion of the dolomitic series.[1]

In North Wales, according to Davidson (fide D. C. Davies),[2] *D. llangollensis* exists in great plenty in the lower beds of the Carboniferous series at the base of the cliffs near Llangollen, and is also found, though not so abundantly, at about the same level at Llanymynech and Porthywaen; in the Eglwyseg cliffs it lies in a shale bed, from which beautiful specimens of the interior of the ventral valve may be obtained. It is, however, important to notice that the generality of the specimens are so imperfect round the margin as to lead one to imagine that they had been drifted from some distance to the spot where they are at present found. At Llandulas, according to Hind and Stobbs,[3] it is found some little distance above the base, and associated with *Seminula* aff. *ficoidea*. It is thought that these limestones cannot be any lower than the junction of the *Seminula* and *Dibunophyllum* Zones of Bristol, and the horizon of the *Daviesiella* is, therefore, regarded as uppermost $S_2$.

*D. llangollensis* is not listed for the Oswestry district by Hind and Stobbs, but it is highly probable that the horizon is the same as in North Wales. Further field-work, however, is necessary in this area, as one would like to know the exact beds from which Ormerod obtained his specimens. The fauna cited by Hind and Stobbs [4] from the Treflach Wood quarries is suggestive of a high horizon in the *Dibunophyllum* Zone, in fact $D_2$; but no fossils are recorded from the well-bedded, dark limestones at the base of the section studied by them.

The species is recorded for Anglesey by Dr. E. Greenly,[5] who lists it among the fossils referred to the $D_1$ sub-zone, to which he attributes the lowest beds of the island. In his description of the Penmon area he points out that the escarpment at the Careg-onen cliffs is composed of rather dark limestones with shale, and has yielded: *Alveolites septosus*, *Syringopora* sp., *Daviesiella llangollensis*, *Spiriferina octoplicata ?*, and *Murchisonia kendalensis*.[6] There appears, however, to be some question as to whether the *Seminula* Zone exists in the island, and it is suggested

[1] In reply to a request from Professor O. T. Jones, Dr. Sibly writes (22.v.22): "I do not know Tidenham Chase, but it is extremely probable that the highest Limestone there is of $S_2$ age; the $D_1$ beds are probably Sandstones."

[2] Davidson, op. cit. (Appendix, 1861), p. 278.

[3] Hind & Stobbs, op. cit., pp. 390 and 498.

[4] Hind & Stobbs, op. cit., p. 450.

[5] Greenly, "The Geology of Anglesey" (*Mem. Geol. Surv.*), vol. ii, 1919, p. 609.

[6] Greenly, ibid., p. 652.

that the lower parts of the Lligwy Sandstone may belong to that zone.[1] This lies at the base of the series and contains blocks of derived limestone, which, however, do not contain any zonal fossils.

In addition to Greenly's records, there is the specimen originally figured by Davidson as found on the beach at Beaumaris by Henry Ormerod.[2]

In the North-Western Province, *D. llangollensis* has been met with by Professor Garwood in the neighbourhood of Kirkby Stephen. In his paper on "The Lower Carboniferous Succession in the North-West of England",[3] he gives a description of the *D. llangollensis* Band (h 9), and says: "This interesting band is confined to the southern end of the Shap and Ravenstonedale districts, where it appears to lie a little above the base of the Lower *Dibunophyllum* Sub-zone, as shown by its position relative to the Bryozoa Band and by its association with *Productus* cf. *maximus*. No specimens of *Dibunophyllum* have, however, been found associated with it. *D. llangollensis* would seem, therefore, to have entered the North-Western Province slightly later than it appeared in North Wales, as its horizon in the latter region is usually assigned to $S_2$ of the South-Western Province." On a later page (p. 504) Professor Garwood points out that the *D. llangollensis* Band occurs only at one place in the North-West Province. It is found in impure shaly limestone, east of Kirkby Stephen railway station (Midland), between the station and Wharton Hall, associated with *Productus* cf. *maximus*. Above the band are cherty limestones, somewhat barren of fossils, and neither *Cyathophyllum murchisoni* nor *Dibunophyllum* occur. It may be pointed out that in this neighbourhood the beds differ both lithologically and palæontologically from the normal development of the Lower *Dibunophyllum* Sub-zone elsewhere, being more argillaceous than in the Shap area.

On the Continent *D. llangollensis* is now known from several places.

In the Avesnes region of North-East France, the species enters in the upper part of the Horizon δ (of Vaughan), which includes the *sublaevis* Oolite with *Cyathophyllum* ϕ and the overlying *Daviesiella* Beds ("*Productus giganteus*" Beds).[4] Details of its occurrence here are given by Dr. A. Carpentier[5] and by Professor G. Delépine,[6] who give the level as between the *Productus sublaevis* limestones and the *Productus cora* oolite.

[1] Greenly, ibid., p. 616.

[2] Davidson, op. cit., 1854, pl. 8, fig. 6 [L9835, Manchester Museum].

[3] *Q.J.G.S.*, vol. lxviii, 1912, p. 478.

[4] Vaughan, "Correlation of Dinantian and Avonian," *Q.J.G.S.*, vol. lxxi, 1915, p. 18.

[5] Carpentier, "Contribution à l'Étude du Carbonifère du Nord de la France," *Mem. Soc. Géol. du Nord*, vol. vii, 1913, pp. 85, etc.

[6] Delépine, "Description du gisement à *Daviesiella llangollensis* de Florennes," *Annales de la Soc. Scient. de Bruxelles*, Session 27th November, 1919, third section (p. 4 reprint).

Professor Delépine, in an interesting paper recording the presence of the Tournaisian in the Boulonnais region,[1] cites the occurrence of *D. llangollensis* in the massive dolomite of Huré. Here the species was met with in abundance, along with gasteropods of large size, and certain brachiopods and corals, sufficient to determine the stratigraphical position of the upper part of the Huré dolomite. The horizon compares favourably with the Horizon δ of the South-Western Province.

In Belgium Professor Delépine has recently recorded its occurrence at Florennes, and cites it from three other places: the Gomezée section, west of Florennes (Dr. A. Carpentier), immediately under the massive white *Productus cora* limestones; Landelies, at the base of the *Productus cora* zone; Sovet, in the Bocq valley, at the top of $S_1$.[2] The position of the limestone containing *D. llangollensis* at Florennes is thought by Professor Delépine to be equivalent to $S_1$, or the summit of $C_2$, of the South-Western Province. From these observations it is concluded that in Belgium and in the North of France this fossil occupies a very definite position, ranging from the *Productus sublaevis* limestones (= upper part of the $C_2$ sub-zone of Vaughan) up to the *Productus cora* oolite (= base of the $S_2$ sub-zone): it attains its maximum of development and of frequency in the beds between these two horizons, that is to say, in the $S_1$ sub-zone.[3]

It is important to add that an example identified as *D. llangollensis* has recently been met with in the Visé limestones in a new railway cutting to the north of Visé, along the route from Aix-la-Chapelle to Tongres. This is reported to have occurred with a fauna typical of the $D_2$ sub-zone.

Returning to the Derbyshire occurrence of *D. llangollensis*, attention might be called to the similarity between the limestones containing this fossil at Topley Pike and the variable basal beds of $S_2$ in the South-Western Province (as in the Avon Section, Burrington Section, etc.). It is of some interest also to note that Professor O. T. Jones, on being shown the section recently, was particularly struck with the peculiar character of the limestones, and remarked upon their close identity with certain beds of Middle Visean age elsewhere.

In my previous note in this Magazine (*ante*, p. 335) I referred the beds, perhaps rather hastily, to the upper part of Horizon δ (i.e. $S_1$), but Professor Jones is inclined to the view that this is much too low, and has expressed the opinion that the beds should

[1] Delépine, "Note sur la position stratigraphique de la Dolomie de Huré (Boulonnais)," *Annales de la Soc. Géol. du Nord*, vol xlv, 1920, pp. 142–5; also Pruvost & Delépine, "Observations sur la faille d'Hydrequen et sur les couches de base du Carbonifère dans le Bas-Boulonnais," *Bull. Soc. Géol. de France*, Ser. iv, vol. xxi, 1921, pp. 189–206.

[2] Delépine, op. cit., 1919 (pp. 3–5 reprint).

[3] Delépine, op. cit., 1919 (p. 5 reprint).

be regarded as $S_2$, probably about the middle of that sub-zone. Pending a detailed study of the overlying Chee Tor Rock I am prepared to accept this view.

In Wye Dale, between the *Daviesiella* exposure and Pig Tor, on the way to Buxton, lower beds are seen, but these have not yet been examined in detail. On close study these may assist in arriving at more definite conclusions.

Where to place the upper limit of *D. llangollensis* also remains for future investigation. It is probable that it may extend up to the base of the massive white limestones of the Chee Tor series.

The latter series is some 500 feet in thickness, and is surmounted by a lava-flow—the Lower Lava of the Miller's Dale area—and this is again overlain by about 150 feet of limestones, mostly thickly bedded, and including some interesting types. One of the most important of these is a mottled bed, observed many years ago by Messrs. J. Barnes and W. F. Holroyd [1] in a small quarry near the Glory Mine at Priestcliffe Ditch, not far from Miller's Dale. The rock consists of a light-coloured and fine-grained "matrix", with dark-coloured irregularly shaped patches of a fine-grained limestone. On microscopical examination the dark patches are seen to contain an abundance of foraminifera, while the lighter "matrix" is practically barren of such organisms. The rock agrees exactly with the well-known "pseudobreccia", which is so characteristic of $D_1$ in the typical Avon Section,[2] and at Gower, etc.[3] A similar "pseudobreccia" also occurs in the higher portions of the $D_1$ sub-zone in the North-Western Province.[4]

Attention might also be called to the occurrence of calcite-mudstone in Sandy Dale, near Miller's Dale, in the same series of limestones lying between the Upper and Lower Lavas. This bed was pointed out to me by Professor O. T. Jones on the occasion of a recent class excursion from the Manchester University. Some little distance above the calcite-mudstone in the same dale, dark limestones with chert-nodules are seen. These contain *Lithostrotion junceum* in abundance, and are very little below the Upper Lava.

In the massive white limestones, about 12 feet above the Lower Lava, in Miller's Dale itself, *Lithostrotion junceum*, *L. irregulare*, and *L. martini* occur, together with *Cyrtina septosa* (quite typical) and *Chonetes* aff. *comoides*.

These limestones, which are part of the Miller's Dale Rock of the Geological Survey,[5] are included by Dr. Sibly in $D_1$, and this is in agreement with the fauna.

The *Cyrtina septosa* from these beds is quite typical of Phillips'

[1] Barnes & Holroyd, *Trans. Manch. Geol. Soc.*, vol. xxvi, 1900, pp. 561–8, pls. 1–11.

[2] See S. H. Reynolds, in *Q.J.G.S.*, vol. lxxvii, 1921, p. 234.

[3] See E. E. L. Dixon, in *Q.J.G.S.*, vol. lxvii, 1911, pp. 560 et seq.

[4] See E. J. Garwood, in *Q.J.G.S.*, vol. lxviii, 1912, p. 477; also J. W. Jackson, GEOL. MAG., 1908, pp. 266–8.

[5] *The Carboniferous Limestone, etc., of North Derbyshire*, 2nd ed. (1887), p. 18.

figure,[1] and differs from the somewhat more transverse form met with in the "Brachiopod Beds" of the Midland area. Good figures of this last variety (which might be called var. *transversa*) are given by Davidson, based upon specimens from Park Hill.[2] I possess examples of the same variety from Middle Hill, near Castleton (associated with *Streptorhynchus senilis* Phil.),[3] and from Narrowdale Hill, near Wetton.

## On the Occurrence of Pre-Cambrian Shale in Guernsey.

By George Horace Plymen, M.Sc., Ph.D., F.G.S.

IT was noted by the Rev. C. Noury[4] in 1886 that sedimentary rocks were found in a small coastal area to the south of Fort Pezerie, on the south-western extremity of Guernsey. Professor T. G. Bonney[5] observed the same area independently in September, 1910, after describing it in field notes in 1888 as a close-jointed and rather schistose diabase. The Rev. E. Hill[6] in 1884 had also regarded the rock in this area as constituting a dyke-formed diabase.

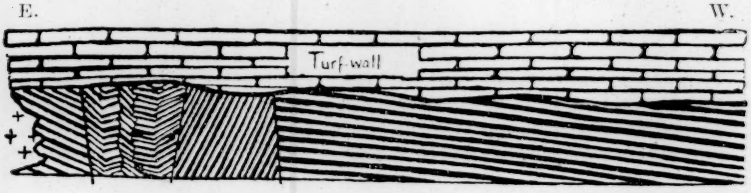


Fig. 1.—Pre-Cambrian Shale, Torteval, Guernsey.

Professor Bonney, on submitting slices of the rock to microscopical examination, defined it as a grit. He recognized sub-angular and fairly rounded quartz, felspar with (in cases) signs of plagioclase, and dark brown, barely translucent, iron oxide in grains. The matrix was observed to be a mozaic of quartz and reconstituted felspar, with films of mica, varying in colour from green to colourless.

Although regarded as pre-Cambrian, this patch of sedimentary rock has not a close similarity to the pre-Cambrian shales of Jersey; but its occurrence in an area of intense crushing and faulting, probably with accompanying metamorphism, gives reason for apparent dissimilarity. It may well represent the quartzose "greywacke" beds, which alternate with more typical mudstones, familiar

[1] J. Phillips, *Geology of Yorkshire*, vol. ii, "The Mountain Limestone," 1836, p. xi, fig. 7.
[2] Davidson, op. cit., ii, pl. xiv, figs. 1–4.
[3] Ibid., ii, pl. xxvii, fig. 2.
[4] *Géologie de Jersey*, par. R. P. Ch. Noury, S.J. 1886.
[5] *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, p. 47.
[6] *Quart. Journ. Geol. Soc.*, vol. xl, 1884, p. 417.

to observers of the Jersey sedimentaries and of the " Phyllades de St. Lô " in Normandy.

While examining this small area in the spring of 1920, with a view to correlation with the Jersey sedimentary beds, the present writer discovered another outcrop near by, which had hitherto escaped the notice of earlier investigators. It was re-examined in April of this year.

The section is a roadside exposure on the Torteval Road, 75 yards to the eastward of Westend Cottage (2 in. Ordnance Survey Sheet of Guernsey).

Westend Cottage is about 2,500 yards S.S.E. of Fort Pezerie, and 1,500 yards due east of Pleinmont Point.

The exposure is 37 yards in extent along the road, showing a height above road level of at most 3 feet. A turf wall, 4 feet in height, has been constructed above it. Outcrop occurs only on the south side of the road.

The rock is a fine mudstone, showing the distinctive appearance, colouring, bedding, and fracture, of the Jersey shales. A green satin-like surface is developed on the bedding-planes, as at St. Lô. Eastward, the beds cease by intrusion of a gneissic rock, which may be tentatively described as of dioritic origin.

At the point of igneous intrusion the beds dip to the north at an angle of 10 degrees. This condition persists for 5 feet westward. For 7 yards, still to west, the shales are broken and crushed, having no recognizable or reliable dip. A further 4 yards westward shows a high dip to the east. The remaining 24 yards exhibit a dip of 10 degrees to the north. There is suggestion of shear through the middle of the section. The exposure occurs along an east-west direction, at an altitude of 210 feet. To the south is nothing but dioritic gneiss, with inadequate evidence of relationship. If the beds continued according to their northward dip, they would reach sea-level about 1,400 yards to the north, thus providing a strike running through the Fort Pezerie area.

Faulting in an east-west direction, rather common in this part of Guernsey, has apparently preserved these small areas by down-throw; a north-south faulting, a very noticeable feature in the south of Guernsey, has restricted the outcrop.

The fact noted by Professor Bonney that " diabase " invades both sedimentary beds and the gneiss, and that all three are invaded by a " red " dyke (the pre-Cambrian aplite, common in all of the Channel Islands), appears to establish the pre-Cambrian age of these beds.

# REVIEWS.

TOPOGRAPHY AND GEOLOGY OF NORTHERN SINAI. Petroleum Research Bulletin, No. 10. By F. W. MOON, B.E., F.G.S., etc., and H. SADEK, B.Sc., F.G.S. Cairo: Government Press, 1921. P.T. 50.

WE owe this important scientific publication to the interest which the Government of Egypt has taken and is taking in the development of the oil resources of the country. It records the observations of two officers of the Geological Survey of Egypt; an institution which geologists of all countries will rejoice to see continued and even expanded under the new regime; for vast tracts of the country still remain unexplored. The main objects of the expedition were, therefore, to look out for evidences of oil, to note the localities where, and the geological formations in which they occur, and to determine the positions of anticlinals, domes, faults, and other structures which must be located before the most promising sites for borings can be selected; in short, to make a geological survey of the area with special reference to oil-problems. The party entered the field in November, 1919, at Suez, arrived at El Arish at the end of February, 1920, having walked well over 1,000 miles, and then returned to Egypt by way of the now celebrated Gebel Maghara massif, reaching Ismailia towards the end of May.

How little was previously known of the area is shown by the fact that when the Geological map of Egypt (1 : 1,000,000) was published in 1910, that portion of the Sinai peninsula which lies north of lat. 29° 30′ was left blank. Now, owing to the work of the authors, we have, in this memoir, a map on a scale of 1 : 250,000 in which 8,000 square kilometres of that blank area are covered with colour, representing nine distinct formations: Alluvium and Recent; Miocene in two divisions (Miocene and Gypsum); Eocene; Cretaceous in three divisions (Campanian and Maestrichtian or Chalk), Santonian-Turonian-Cenomanian; "Nubian" and Lower Cretaceous; Jurassic; and igneous intrusions. The authors correctly describe their work as a reconnaissance survey; but owing to the excellent exposures, the persistence of easily recognizable lithological divisions, the generally favourable climatic conditions—heavy rains, hail-storms, blizzards, and intense cold are not wholly unknown as the authors have reason to remember—the close relation between topography and geological structure, and the possession of admirable field maps [1] (1 : 125,000), issued by the War Office in 1915, much more has been accomplished than would have been possible in a country where these conditions do not exist.

In addition to the map, the volume contains nine plates of sections,

[1] These maps, with the geological information, are published separately (seven sheets, price P.T. 20 per sheet).

orographical maps, etc., and sixty-nine photographs, which are really plates though not numbered as such. Two photographs are usually printed on a page, but there are also several folded panoramic views representing features of special interest. A straight line drawn from El Arish to a point on the gulf about 40 kilometres south of Suez passes through the centre of the area, which is over 60 kilometres across at its widest part, closing in to about 15 kilometres on Wadi el Arish and 30 at the Gulf of Suez.[1]

The authors begin by giving a succinct account of the route followed. Anyone who reads this account, referring constantly to the maps and photographs, will obtain a vivid impression of the physical features and geological structure of the area, especially if he has previously made himself familiar with the general succession as described in Chapter II.

The region contains two large plateaux of Eocene limestone, Raha and Muksheib; three massifs of Upper Cretaceous, Giddi, Fallig, Yellig; and one of Jurassic and Lower Cretaceous partially encircled by Upper Cretaceous. The Raha, Giddi, and Muksheib highlands follow each other from south to north at elevations of 1,800 feet and over. Though separated by low passes, they may be regarded as one orographical group. This group and the other highlands are surrounded by vast stretches of sand and gravel at lower levels. The western edge of the Raha plateau is sharply defined by a north–south fault, running approximately parallel with the eastern shore of the Gulf of Suez, at a distance of about 25 kilometres, and known to extend far to the south. Between this fault and the shore is a belt of Miocene rocks traversed by numerous faults parallel to the main one. East of this fault-zone the whole of the area surveyed is dominated by structural features of an entirely different kind. Broadly speaking, the rocks are gently folded so as to form anticlinal and domal structures along slightly curved lines, bulging towards the south and extending from the zone of north–south-faulting right across the area to Wadi el Arish. In the west these lines run nearly east and west, but as they are traced eastward they become E.N.E.–W.S.W. Three such lines or axes are recognized; the Giddi-Yellig-Hellal axis in the south, the Maghara axis in the middle, and the Hamaiyir-Reisan axis which is only slightly north of the last. Although gentle folding is characteristic of the district as a whole, there are "steep dip zones" and local disturbances of great intensity, as well as many faults. In Chapter III the authors give detailed descriptions of the topography, stratigraphy, structure, and palæontology of nine separate districts, carefully recording any evidences of oil-impregnation and the occurrence of domal structures.

[1] Readers shou'd refer to the paper by Dr. Hume and others on "The Jurassic and Lower Cretaceous Rocks of Northern Sinai", and especially to the maps which illustrate that paper. GEOL. MAG., Vol. LVIII, 1921, pp. 339–47.

To note the many other interesting features of this memoir is impossible; only one or two will be referred to. The history of the discovery of Jurassic and Lower Cretaceous rocks in Northern Sinai in which Barthoux, Fourtau, and Douvillé have each played important parts, together with some account of the later researches recorded in this memoir, have been given by Dr. Hume in the paper already cited and need not be summarized here. The Jurassics resting on sandstones of "Nubian" type range from Bajocian to Callovian and the Lower Cretaceous from Barremian (according to Douvillé) to Albian. All the subdivisions established by Douvillé have been recognized by Sadek and Moon, with the possible exception of Barremian. The scale of the map and the time at their disposal did not allow them to trace out these various subdivisions, but they describe their lithological characters and give lists of the fossils which they collected from each horizon.

The Nubian sandstone question is discussed at some length and Douvillé's view (1916) that the term should be restricted to pre-Bajocian sandstone is repeated. The authors point out that the so-called Nubian sandstones of Egypt and Sinai are now known to be of different ages in different places—and suggest that the use of the term should be dropped whenever the age of the sandstone can be determined. No traces of marine Jurassic or Lower Cretaceous rocks have as yet been recognized in Egypt or Sinai south of the latitude of the Maghara area. In this connexion it is interesting to note that in Central Sinai, about 100 miles south of Maghara, the long period of time which elapsed between the deposition of the Carboniferous limestone and the Cenomanian is represented by 650 metres of sandstones of Nubian type, conformable to the rocks below and the rocks above, in which no break can be detected.[1] What will be found in that 100 miles of unexplored territory? It is to be hoped that before long the Geological Survey of Egypt will be able to answer this question.

Igneous intrusions play a very subordinate part in the geological history of the district. They are represented only by two or three basalt dykes and sills, presumably of Miocene age.

In discussing the oil prospects of the area the authors speak very guardedly. No actual seepage of free oil has been observed either in the Miocene rocks near the coast or in the Eocene, Cretaceous and Jurassic rocks which lie east of the north–south fault, but oil-stained, oil-impregnated, and oil-smelling rocks are noted as occurring in many localities, and "the structure (consisting of long anticlines on whose crests domes of considerable size are situated) is in several instances very favourable". Oil impregnation was noted at several places in the Chalk (Campanian) and in the Cenomanian, which is referred to as a possible oil horizon. The authors point out

[1] See Ball on the *Geography and Geology of West Central Sinai*. Cairo: Government Press, 1916. Reviewed in GEOL. MAG., 1917, p. 80.

that some geologists are inclined to regard evidence of oil impregnation in a desert country as equivalent to genuine seepages in moister regions. The whole question is discussed in a scientific manner with reference to transport, presence of reservoir- and cap-rocks, domal structures (of which a list is given), and faults. The authors conclude by specifying, as requested, two localities which they regard as slightly more favourable for test-wells than any of the others.

J. J. H. Teall.

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Summary of Progress of the Geological Survey for 1920. Mem. Geol. Survey. pp. v+112, 3 figs. 1921. Price 3*s.* 6*d.*

THE Summary of Progress of the Geological Survey for the year 1920 records the work of the Survey for the first year under the Directorship of Dr. J. S. Flett, under whom its high standard of efficiency will no doubt be maintained.

In order to accelerate the revision of the maps in the coalfield areas, reorganization of the field units has been made and the staff expanded accordingly. The plan of decentralization will no doubt allow the work and experience of the officers of the Survey to be utilized more completely by the public as a whole, since they will be more accessible for consultation on the spot at the local offices.

Field work has been carried out in all the districts where work was in hand before the war. Perhaps the most interesting results achieved are those in the English Midlands and the West Highland District of Scotland. In the Midland area the Silurian rocks afford fresh evidence of Jones' contention that the so-called Upper Llandovery represents the sandy facies of the Tarannon, in which case it is not surprising that the Tarannon Shales have been looked for in vain. The close agreement of the higher beds with those of the typical Ludlow area is also of interest. With regard to the latest glacial deposits, significant features are the occurrence of sands and gravels deposited as a series of fans which mark the successive stages of the ice front instead of terminal moraines.

In the West Highlands the completion of the mapping of Mull foreshadows the publication of the eagerly awaited memoir on that area. Detailed work in Iona has revealed the existence of a platform of Lewisian Gneiss overlain by Torridonian sediments. The Archean complex is very varied, and appears to include both the ortho- and paragneisses and a group of schists composed in part of highly altered sediments, of which the well-known Iona marble is one. Of special interest are the pegmatites, which are quite unfoliated, and therefore later than the metamorphism and the shearing movements.

On the palæontological side by far the most significant feature of the year's work is the discovery of an undoubted Rhaetic fauna in beds at Grubin, Mull, where for the first time Rhaetic beds in situ are recognized in Scotland.

Attention must also be called to the rocks in the Northern Highlands, which are believed to be hybrids between a scyelite and a granite. In a very different field Dr. H. H. Thomas has brought the wide range of his petrological knowledge to bear on the vexed question of the origin of the famous "Blue Stones", forming the inner circle and inner horseshoe of Stonehenge; twenty-nine out of the thirty-four "foreign" stones there are identified as a spotted diabase practically identical with that of the Prescelly Mountains in Pembrokeshire, and three of the remainder appear to be a finely banded rhyolite from the same locality. There can be little doubt that they were transported to their present site by human agency.

Valuable appendices as usual conclude the Summary. In one the succession of Highland Schists displayed along the Banffshire coast is described by Mr. Read, who puts forward a tentative but highly suggestive correlation of these with the schists of other Scottish areas. Another by Mr. MacAlister deals with the production of tin ore and other minerals in various parishes in Devonshire, and gives the results in tabular form so as to bring out the economic value of different tracts in the county.

G. L. E.

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Beiträge zur Kenntnis der Kreideflora. I: Über einige Kreidepflanzen von Swalmen (Niederlande). R. Kräusel. Mededeelingen van 'S Rijks Geologischen Dienst. Ser. A, No. 2, 1922.

In this paper Dr. Kräusel gives a very clear and careful account of a small collection of fossil plants obtained at a depth of 653-659 metres, from a boring at Swalmen, in Holland. Some of the specimens were fortunately carbonized and amenable to treatment by well-known chemical methods for demonstrating the structure of epidermal cells and stomata. The descriptions and photomicrographs are good and most of the photographs of the actual specimens are satisfactory. The author shows an admirable restraint in the identification of the plants, and does not employ names implying affinities to recent genera without adequate evidence. He errs, if he errs at all, on the side of caution; the fern fragments described as *Didymosaurus comptoniæfolius* Deb. and Ett., are almost certainly Gleicheniaceous, and might well be included in *Gleichenites*. The beds are believed to correspond to the middle portion of the Aachen sands, the flora of which was described many years ago by Debey and Ettingshausen, and they are referred to the Senonian. One species of fern is identified, the following conifers: *Araucaria crassifolia*, *Elatocladus elegans*, *Myriconia cyclotoxon*, *Sequoia Reichenbachii*, *Sequoia* sp.; also three species of Dicotyledons, referred to *Myrica*, and a few other Dicotyledonous leaves not determinable with certainty. Associated with some of the cuticular preparations are fungal hyphæ, and in this connexion it is pertinent to suggest that the dark spherical bodies shown in plate v on the

cuticle of a *Myrica* may possibly be small fructifications of an Ascomycetous fungus; they bear a superficial resemblance to undoubted fructifications recently found by the reviewer on similar preparations of cuticles of Cretaceous leaves from Greenland. A very useful bibliography accompanies the paper. Dr. Kräusel's contribution is a welcome addition to palæobotanical literature and the work reaches a high standard.

A. C. S.

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Tektonická Geologie, se zvláštním zřetelem k potřebám báňských techniků. (Tectonic Geology, with Special Regard to the Needs of Mining Engineers.) By B. Stočes. Four plates and 256 illustrations in the text. Moravská Ostrava, 1921.

ATTENTION should be called to a first-rate textbook of tectonic geology for mining engineers and students of mining, recently issued by Professor Stočes of the University for Students of Mining in Přibram, Czechoslovakia. The object of the book is to instil practical knowledge. Merely theoretical reflections are reduced to a minimum size. It gives exceedingly clear notions of all tectonic terms and facts by defining them in a few precise words. It sets forth the methods of ascertaining the geological structure, how faults and the like show themselves in the landscape, in profiles and maps, on the influence exercised by tectonics in the broadest sense of this term on mining and quarrying, insisting on the favourable and unfavourable influences they may exercise on the management and profitableness, and dwelling on often committed mistakes arising from not sufficiently taking into account the structure of a district.

Up till now the book has only appeared in Czech, and while we should recommend an English translation to make it more generally available, we advise everybody who has to deal with Czech geological literature to use the Czech text as a kind of technical cyclopædia. The many carefully selected illustrations, diagrams, maps, profiles, and photographs help in the understanding of the text, as scarcely a single word is left unexplained by some sketch or other.

The examples are mostly chosen from the district around Přibram, the regions of the "Barrandeum" and of the Central Bohemian granite mass, famous for the problems they offer to the geologist. As Professor Stočes and his friend, Professor Kettner, to whom the book is dedicated, have devoted themselves to the study of these problems—in fact, we are indebted to them for all our modern knowledge of this region—the book will at the same time prove an excellent, though naturally unsystematic, guide to the regional geology of central Bohemia.

Dr. T. Moscheles.

THE BIOLOGY OF THE SEA-SHORE. By F. W. FLATTELY and C. L. WALTON, with an introduction by Professor J. ARTHUR THOMSON. pp. 336, with 16 plates and 23 text-drawings. London: Sidgwick & Jackson, Ltd., 1922. Price 16*s.* net.

THIS is a work upon a hitherto neglected branch of bionomics, and as such we can cordially recommend it. It aims at showing how the animals and plants inhabiting the sea-shore interact, and how the environment influences their structure, functions, and habits. It is well illustrated by a number of excellently chosen photographs and drawings. The chapters that will be of most interest to the geologist are those upon the physiography of the sea-coast, and its plant and animal associations. The account of the zoning on the rocky shore of Cardigan Bay is particularly instructive, and the authors record the succession of nine species of Trochidæ and Littorinidæ, and show how these are correlated with different conditions of shore drainage and the type of rock or soil from which it flows, as well as probably with the lime content of the water. Among many other matters of interest investigated by the authors and here described is the colonization of the Kiel Canal by marine forms in a definite ecological succession.

F. H. A. M.

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STRATIGRAPHY, STRUCTURE, AND POSSIBLE OIL RESOURCES OF THE MIOCENE ROCKS OF THE CENTRAL PLAIN, REPUBLIC OF HAITI. By W. P. WOODRING. pp. 19, with a map. Washington, 1922.

THE United States Geological Survey has been lately engaged on behalf of the government of Haiti in carrying out a reconnaissance survey of the territory of the Republic: the results of this work are soon to appear, but the present section has been published in advance on account of the oil possibilities of the region described, which consists of folded Miocene strata, overlain by nearly horizontal Pliocene. Descriptions are given of the lithological characters of the Miocene strata, which have a maximum thickness of about 1,400 metres and are folded into a synclinorium striking north-west-south-east. This series is called the Artibonite group, and contains numerous shallow-water marine fossils, many still undescribed. The map shows structures very favourable to oil accumulation, and it is considered that exhaustive tests should be carried out by drilling on the crests of the numerous minor anticlines.

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THE IRON-ORE RESOURCES OF EUROPE. By MAX ROESLER. Bulletin 706, U.S. Geol. Survey. pp. 152, with xix plates (maps) and 33 text-figures. Washington, 1921.

THIS Bulletin is avowedly a compilation, having been drawn up as part of the work of determining the extent and position of foreign mineral deposits for the guidance of the American Peace Commission. It is thus liable to the common defect of such com-

pilations, in that the sources of available information are of unequal value and reliability. To take a concrete example, it must be frankly said that the account of the iron ore resources of the British Isles is inadequate and misleading: unfortunately the recent admirable publications of H.M. Geological Survey on this subject are not mentioned and have evidently not been consulted, and the map of the Cleveland district is entirely unintelligible to the reviewer, although it is said to be reproduced from "The Iron-Ore Resources of the World" (International Geological Congress, 1910). Good summaries are given of the minette ores of Lorraine, of the Spanish deposits, and of the very interesting magnetite and other ores of Sweden.

The author has ransacked very fully the available literature on the less-known localities, and has compiled an extremely useful bibliography, arranged by countries.

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THE GEOLOGY OF THE PLATEAU TIN FIELDS. By J. D. FALCONER. Bulletin I, Geological Survey of Nigeria. pp. 55, with 10 plates and a coloured geological map. Published by the Nigerian Government, 1921. Price 10*s.* net.

THE Geological Survey of Nigeria was established in 1919, under the direction of Dr. J. D. Falconer: it has lost no time in giving tangible proofs of its activities in the form of this and other memoirs that have recently come to hand. The economic importance of the tin deposits of Northern Nigeria is well known and the geology presents some points of interest. The area here described consists of a fundamental complex of ancient schists and gneissose granites, the last named apparently of more than one age. At a later, but unknown date, this complex was invaded by a great granite batholith with a very irregular upper surface, now forming seven main outcrops or groups of outcrops: with this intrusion are associated numerous dykes and an extensive and well-marked mineralization of the cassiterite-wolfram-topaz type, tourmaline being rare. The Plateau granite carries mainly biotite, but locally there are highly alkaline facies with riebeckite. Some of these types have been described in more detail by Major Williams, to whose paper in the GEOLOGICAL MAGAZINE no reference appears to be made: throughout this memoir very few references are given to previous literature.

As in most tin-mining districts, nearly all the production has hitherto come from alluvials, but in many localities there are promising indications of the presence of stanniferous veins and lodes, though none yet appear to have been worked with success. It is possible that much of the most highly mineralized granite has already been removed by denudation and distributed into ancient or modern alluvial deposits.

A considerable part of the district here described is covered by what is called the Fluvio-Volcanic Series, consisting of much-decomposed lavas and redistributed volcanic material, partly burying, as

before mentioned, the older tin-bearing alluvium: this must not be confused with the Tertiary volcanic series, comprising many ash cones and necks and flows of olivine-basalt. This formation also gives rise to deep leads by burying old valleys.

The Bulletin is excellently illustrated by photographs of local scenery and microphotographs of rocks, and is accompanied by a well-printed coloured geological map on the scale of half an inch to the mile.

THE JOHNS HOPKINS UNIVERSITY STUDIES IN GEOLOGY.

No. 1.—THE GEOLOGY OF THE COROCORO COPPER DISTRICT OF BOLIVIA. By J. T. SINGEWALD, jun., and E. W. BERRY. pp. 115, with 7 plates. Baltimore, 1922. Price $1·25.

No. 2.—THE GEOLOGY AND PALÆONTOLOGY OF THE HUANCAVELICA MERCURY DISTRICT. By E. W. BERRY and J. T. SINGEWALD. pp. 101, with 10 plates. Baltimore, 1922. Price $1·25.

THESE publications are the first of a series of monographs to be issued by Johns Hopkins University devoted to the presentation of the results of geological investigation in its broadest sense. The first few numbers will give the results of the Williams Memorial Expedition to South America, while later monographs will be of more general character.

The Corocoro copper deposits have yielded a very large amount of copper and some silver from deposits of a peculiar character: namely, from native copper occurring in beds of red sandstone of Tertiary age. Of late years, however, at greater depths it is found that the native metal gives place to sulphides, which have been successfully worked by flotation. The red rocks, including sandstones, shales, and conglomerates, are divided into two series, the Vetas and the Ramos, whose relationship is still uncertain; the meagre palæontological evidence suggests that the Vetas are Pliocene and the Ramos a little younger. The Vetas have yielded representatives of twenty-three species of plants, mainly Dicotyledons, including thirteen species of Leguminosæ. Full descriptions of the plant remains are given in the memoir.

Although mercury is widely distributed in Peru, the only district with a large output is Huancavelica, which is known to have produced altogether about 56,000 tons of the metal. The region consists of a highly inclined series of fossiliferous Cretaceous sediments, with volcanic rocks of later, probably Tertiary age. The mercury ore, cinnabar, chiefly occurs as disseminations and veins in the Grand Farallón sandstone member of the Cretaceous and in limestones. The limestones have yielded a fairly abundant Upper Cretaceous fauna showing considerable resemblance to the so-called Comanchean faunas of Texas and Mexico, and still more like the Upper Cretaceous fossils of North-West Africa and the Iberian peninsula: about forty forms are described in detail.

HANDBOOK TO HULL AND THE EAST RIDING OF YORKSHIRE. Edited by T. SHEPPARD, M.Sc., F.G.S. (British Association, Hull Meeting). pp. 532, with plates and figures (not numbered). London and Hull: A. Brown & Sons, Ltd., 1922.

THIS handsome volume, prepared as the local guide for the Hull meeting of the British Association, contains a large number of special articles on the East Riding of Yorkshire. The section on geology, presumably written by Mr. Sheppard, though short, is much to the point, and gives an excellent summary of our present knowledge of this interesting area, which presents many remarkable features and has been described in so many classical memoirs. The sections on coast-erosion and geographical changes, as well as a short chapter on the North Sea by Mr. A. N. Somerscales, also present matter worthy of the attention of geologists. Mr. Sheppard is to be congratulated on the results of his editorial labours, which, as may be gathered from the preface, appear to have been unusually arduous.

## REPORTS AND PROCEEDINGS.

BRITISH ASSOCIATION, HULL MEETING, 1922.

*Papers read in Section C.—Geology.*

Presidential Address: The Physiography of the Coal Swamps; Professor P. F. Kendall.

1. Discussion on the Geological History of the North Sea Basin; opened by Professor P. F. Kendall.
2. Lecture on the Geology of the Hull District; Mr. T. Sheppard.
3. The Erosion of the Holderness Coast; Mr. C. Thompson.
4. Pleistocene and Recent Ice Conditions in North-Eastern Labrador; Professor A. P. Coleman.
5. A new section in the Oolites and Glacial Deposits at South Cave; Mr. J. W. Stather.
6. Sandstone Dykes or Rock-Riders in the Cumberland Coalfield; Professor A. Gilligan.
7. Discussion on Wegener's Hypothesis of Continental Drift; opened by Dr. J. W. Evans; with contributions by Professor H. H. Turner and Mr. W. B. Wright.
8. The Relation of the River Thames to the London Basin; Professor H. L. Hawkins.
9. Joint Discussion with Sections E and H on the Relation of Early Man to the Phases of the Ice Age in Britain.
10. Goniatite Zones in the Middle Carboniferous; Mr. W. S. Bisat.
11. A Type Section of the Yoredalian; Mr. R. G. Hudson.
12. A New Section in the Oolites at North Ferriby; Mr. W. S. Bisat.
13. Reports of Research Committees.